Jones Creek Pink Salmon Spawning Channel: A Biological Assessment, 1954-1982

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A BIOLOGICAL ASSESSMENT, 1954 - 1982

by

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ABSTRACT

F.J. Fraser and A.Y. Fedorenko. 1983. Jones Creek pink salmon spawning channel: a biological assessment, 1954-1982. Can. Tech. Rep. Fish. Aquat. Sci. 1188:89 p.

This report describes the Jones Creek spawning channel and its operational history; presents fisheries biological information on the system from 1954 to 1982, particularly for pink salmon; assesses the success of the spawning channel in maintaining the Jones Creek salmon stocks after hydrodam construction; and examines the current problems regarding channel operation.

Key words: Jones Creek spawning channel, pink salmon.

RÉSUMÉ

F.J. Fraser and A.Y. Fedorenko. 1983. Jones Creek pink salmon spawning channel: a biological assessment, 1954-1982. Can. Tech. Rep. Fish. Aquat. Sci. 1188:89 p.

Le présent rapport décrit la frayère artificielle du ruisseau Jones et ses antécédents opérationnels, présente des données biologiques sur le système pour la période de 1954 à 1982, surtout sur la pêche du saumon rose, évaue le succès de la frayère artificielle pour ce qui est du maintien des stocks de saumon du ruisseau Jones après la construction d'un barrage hydro-électrique et examine les problèmes actuels relatifs à l'exploitation de la frayère.

Mots-clés: frayère artificielle du ruisseau Jones, saumon rose.

INTRODUCTION

In 1952, the B.C. Electric Co. (now B.C. Hydro and Power Authority) constructed a hydroelectric storage dam 1.2 km below Wahleach (Jones) Lake outlet (Fig. 1). The Wahleach hydroelectric project resulted in the diversion of a large portion of the natural water flow from Jones Lake into penstocks, delivering 6.14 m^3/sec to the Wahleach power generating station located 13 km downstream from the mouth of Wahleach (Jones) Creek, adjacent to the Fraser River (Fig. 1).

The project proposal, made in 1949, aroused the concern of the Department of Fisheries and Oceans (DFO) since construction of the dam would seriously disrupt the Jones Creek flow and substantially reduce the spawning area of salmon. This would affect particularly the pink salmon (Oncorhynchus gorbuscha), the principal species in the system during odd-numbered years, but also the annual small runs of chum salmon (O. keta) and coho salmon (O. kisutch).

Section 21 of the Fisheries Act requires that the owner of a dam or other obstruction must pay for the construction, operation and maintenance of any facility the Minister deems necessary to maintain the existing fish stocks. In view of this, DFO conducted from 1949 to 1951 engineering surveys and the first intensive biological surveys of the Jones Creek salmonid resource (Wickett 1952; Neave and Wickett 1955). In particular, the 1949 survey included estimates of the pink, chum, and coho escapements by tagging and by live and dead counts; cataloging of preferred spawning areas; periodic sampling of selected redds to determine the incubation period and timing of fry emergence; and fry sampling to determine juvenile migration timing.

After completion of the surveys, DFO presented the power company with four remedial proposals:

1. maintaining a minimum flow of 1.4 m^3/sec,
2. maintaining a minimum flow of 0.6 m^3/sec in a controlled channel,
3. constructing and operating a hatchery, and
4. transplating the pink salmon run.

Based on factors such as water requirements, initial expenditures, and annual operating costs, the B.C. Electric Co., by mutual agreement with the DFO, chose to build, operate and maintain a controlled flow spawning channel. They also guaranteed to supply the water flow necessary to operate the channel during spawning and incubation of the odd-year pink salmon runs. The basic design for the channel was provided by the engineering staff of DFO, and the details of the design and construction were completed by the power company.

The Jones Creek spawning channel was completed in September 1954, almost two years after the generating station was put into service. This was an off-cycle year for pink salmon, and only a few coho spawned in the channel that year; the earlier arriving chum had difficulties entering the channel and spawned only in the lower Jones Creek (Hourston and MacKinnon 1956). Pink salmon have spawned naturally in the channel since 1955. The 400 pink adults

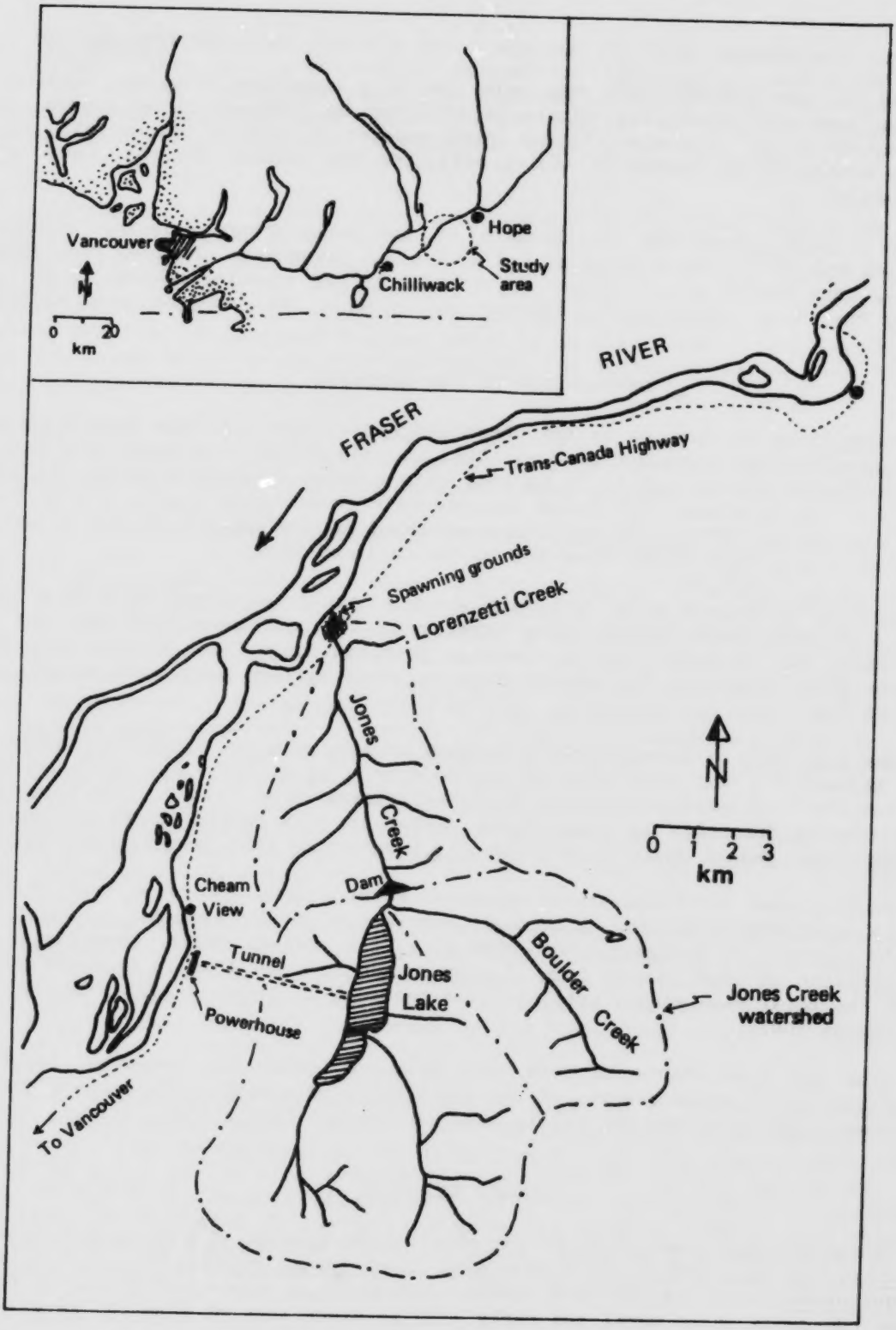


Fig. 1. Location of Jones Creek and of the power development project.

observed in the channel that year were the only survivors from the original odd-year pink run which was adversely affected by reduced flows caused by construction of the hydroelectric dam (MacKinnon et al. 1961). Since 1955, the DFO has monitored the number of adults utilizing the channel and the number of fry produced.

This report describes the history of the Jones Creek spawning channel operation and the relevant physical and biological parameters obtained from 1954 to 1982. The report also assesses the success of the spawning channel in maintaining the Jones Creek salmon stocks, particularly the odd-year pink salmon runs.

DESCRIPTION OF THE WATERSHED

Jones Creek is located in the Cheam Ridge and flows into the Fraser River approximately 16 km southwest of Hope (Fig. 1). The creek originates from Jones Lake (elevation 687 m) and is 10 km long with a total drainage area of 122 km^2 (Fig. 1). The drainage area below the dam site constitutes nearly 20% of the total area (Anon. 1949). The tributary watershed is bowl-shaped and the terrain relatively steep with slopes from 30% to 70% (Wilford 1975).

Boulder Creek is a major tributary which enters Jones Creek 150 m from the lake; Lorenzetti Creek enters Jones Creek near its confluence with the Fraser River (Fig. 1). Cascades, 0.8 km upstream from the Jones Creek outlet, totally obstruct salmon passage; the overall drop in water surface over this stretch of creek is 7 m.

The discharge of Jones Creek, like that of many other northwestern streams, peaks between May and July when the mountain snow is melting, but the creek is also subject to flash floods during heavy rainstorms (Anon. 1949). For example, the estimated discharge at Jones Creek outlet in 1919 peaked at 47 m^3/sec in late May, then peaked again at 69 m^3/sec in November of that year (Anon. 1949).

Monthly mean air temperatures measured at Hope (Fig. 1) range from 18.5°C in July to -0.4°C in January, with daily extremes of 40.0°C recorded in July and -24.4°C recorded in December (1951-1980 data, Env. Canada 1982). Monthly mean precipitation at Hope ranges from 37.0 mm in July to 289.4 mm in December with 11% of the total mean annual precipitation recorded as snowfall (1951-1980 data, Env. Canada 1982).

From the late 1960's to 1979, the Whonnock Lumber Co. conducted logging operations in the upper reaches of the Jones Creek watershed. The company plans to resume logging operations in the area by the mid-1980's (Bill Gilpin, pers. comm).

FISHERY RESOURCE

Historically, Jones Creek supported all five species of the Pacific salmon (Oncorhynchus spp.) and a run of steelhead trout (Salmo gairdneri). Pink salmon (O. gorbuscha) were the dominant species and averaged approximately 4,250 fish in the odd-cycle years until the early 1950's; minor runs of chum (O. keta) and

coho (O. kisutch) averaged annually about 450 and 200 fish respectively during that period (Table 1). A very small chinook (O. tshawytscha) population and about 700 sockeye (O. nerka) were also observed annually until 1941, but no further records exist of their occurrence and reasons for their disappearance are not known. Approximately 25 steelhead trout also spawn annually in the creek.

Spawning grounds in Jones Creek are confined to the lower 0.8 km by the cascades. Chum arrive first in late August and early September with peak spawning occuring in late September. Pink salmon arrive in mid-September with peak spawning occuring in mid-October. Both chum and pink complete their spawning by the end of October. Coho arrive in early November with peak spawning occuring in late November and ended by late December. Steelhead trout enter the creek later in the year and through the following spring, but their timing and numbers are not monitored.

Some coho and steelhead juveniles utilize the channel and creek for rearing. In addition, small populations of chum, pink and coho salmon spawn in Lorenzetti Creek, a lower tributary to Jones Creek (Marshall et al. 1980).

CHANNEL DESIGN AND PHYSICAL DESCRIPTION

The Jones Creek spawning channel was built during 1953/1954 and was the first controlled-flow artificial spawning channel constructed on the North American continent. The channel was designed to accommodate approximately 6,000 pink adult spawners in odd-numbered years in a spawning area of approximately 1800 m^2 estimated to be the natural spawning area available in Jones Creek prior to dam construction. The above design allowed an average of 0.6m^2 per female pink salmon (MacKinnon et al. 1961). The channel design was also set to duplicate the gravel size, stream gradient and water velocities considered optimal for spawning in natural streams.

The spawning channel was constructed adjacent to Jones Creek and was designed to be 3 m wide at the bottom and 585 m long, with gravel-lined sides having slopes of 1 1/2: 1 (Fig. 2).

The intake structure consisted of a reinforced concrete box with a 1 m diameter Calco valve for the regulation of flow, connected to a 21 m long, 1 m diameter, 12-gauge corrugated pipe which passed through a dyke to the top end of the spawning channel. To maintain a sufficient water head for the intake pipe, a low concrete dam was built downstream of the intake box across the original creek.

The intake structure was designed to pass flows up to 1.4 m^3/sec into the channel and to bypass excess water through the Jones Creek flood channel. In order to maintain the required discharge to the channel when the residual flow dropped below 0.6 m^3/sec (the average flow required for channel operation), an outlet control works capable of passing 0.85 m^3/sec was installed in Boulder Creek (Fig. 1). Because of low water problems at spawning time in some years, B.C. Hydro utilized pumps (from 1957) and later installed a siphon inflow from Jones Lake which could be used to maintain adequate spawning flows.

Table 1. Estimated annual escapements of pink, chum, coho, sockeye, chinook and steelhead into Jones Creek prior to channel construction (1934-1953), and into Jones Creek channel, Jones Creek and total system from 1954 to 1981.[a]

Year	PINK Creek	CHUM Creek	COHO Creek	SOCKEYE Creek	CHINOOK Creek	STEELHEAD Creek
1934	-[b]	75	25	3,000	25	-
1935	250	25	75	200	25	-
1936	-	75	400	400	75	-
1937	250	400	400	400	few	-
1938	-	400	400	400	25	-
1939	400	400	400	400	25	-
1940	-	400	400	400	25	-
1941	4,000	200	400	400	25	-
1942	-	200	200	-	-	-
1943	7,000	200	200	-	-	-
1944	-	50	200	-	-	-
1945	7,000	400	200	-	-	-
1946	-	3,000	200	-	-	-
1947	7,500	200	200	-	-	-
1948	-	400	200	-	-	-
1949	6,300	500	200	-	-	-
1950	-	750	-	-	-	-
1951	6,300	400	25	-	-	-
1952	-	750	75	-	-	-
1953[c]	3,500	25	-	-	-	-
Mean[d] (1934-1953)	4,250	443	210	700	28	-

Year	PINK Creek	PINK Channel	PINK Total	CHUM Creek	CHUM Channel	CHUM Total	COHO Total	SOCKEYE Total	CHINOOK Total	STEELHEAD Total
1954[e]	-	-	-	100	-	100	28	-	-	-
1955	N/A[e]	400	400+[f]	N/A	160	~200	25	-	-	-
1956	N/A	2,800	2,800+	30	300	330	25	-	-	25
1957	962	1,056	2,018	26	27	53	25	-	-	25
1958	-	39	39	N/A	-	~200	75	-	-	-
1959	455	2,119	2,574	19	71	90	25	-	-	25
1960	-	-	-	400	-	400	75	-	-	25
1961	789	4,368	5,157	26	65	91	75	-	-	25
1962	-	-	-	25	-	25	75	-	-	25
1963	700	2,806	3,506	19	138	157	75	-	-	25
1964	-	-	-	75	-	75	75	-	-	25
1965	782	2,147	2,929	30	37	67	75	-	-	25
1966	-	-	-	25	-	25	75	-	-	25
1967	869	2,874	3,743	33	33	66	25	-	-	-
1968	-	-	-	500	-	500	30	-	-	25
1969	488	1,319	1,807	111	100	211	65	-	-	-
1970	-	-	-	200	-	200	150	-	-	-
1971	629	1,194	1,823	8+	5+	~25	25	-	-	-
1972	-	-	-	300	-	300	50	-	-	30
1973	1,162	1,851	3,013	159	248	407	125	-	-	-
1974	-	-	-	100	-	100	100	-	-	-
1975	650	2,046	2,696	100	34	134	20	-	-	-
1976	-	-	-	35	-	35	-	-	-	-
1977	1,363	1,911	3,274	106	179	285	N/A	-	-	-
1978	-	-	-	150	-	150	-	-	-	-
1979	723	3,567	4,290	71	63	134	N/A	-	-	-
1980	-	-	-	N/A	-	N/A	N/A	-	-	-
1981	1,617	1,890	3,227	230	157	387	-	-	-	-
Mean[d] (1954-1981)	881	2,153[g]	2,882[g]	115	107	175	60	-	-	25

[a] Excludes Iowamatti Creek.

[b] No run observed.

[c] Salmon runs affected by reduced flow prior to channel operation.

[d] Excludes years with no run or data.

[e] Data not available.

[f] Underestimated due to lack of data.

[g] Excludes 1958 data (transplant returns).

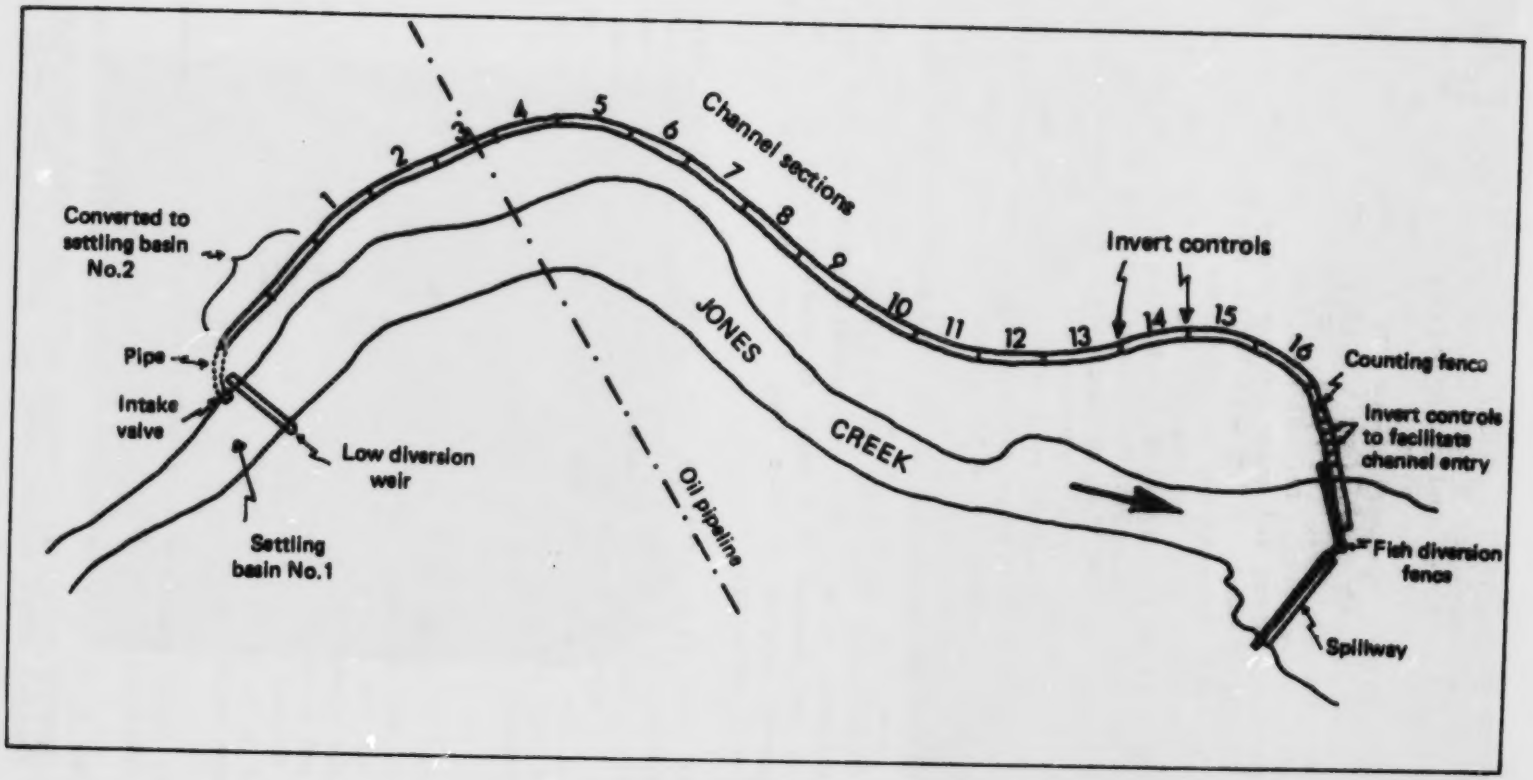


Fig. 2. Jones Creek spawning channel after 1973 (diagrammatic).

The channel was designed for a flow of 0.8 m^3/sec during spawning with a reduction to 0.4 m^3/sec or lower during incubation, and for a water depth range from 30 cm to 60 cm. Since the natural channel slope was greater than that required to maintain the necessary depth of flow (elevation decrease from channel intake to outlet was 5 m), invert controls made of two 10 cm x 15 cm timbers were installed at 30 m intervals throughout the channel length to control water depth and velocity. Drop at each invert control varied from 10 cm to 30 cm depending on gradient and other considerations. However, the gradient and turbulence at the channel outlet were still too high and the first chum spawners failed to enter the channel in 1954, the year of project completion (Fletcher 1957). Consequently, the channel was modified with the installation of more invert controls at the downstream end which helped to control the flow. The single drop at the entrance to the channel was replaced by three smaller steps which were easier for the fish to negotiate. Modification of the entrance was completed by October 15, 1954 (Hourston and MacKinnon 1956). In 1973, the channel outlet was further modified to increase depth and velocity in order to facilitate the entry of pink salmon; six invert controls were installed at 4.5 m intervals at the channel outlet below the enumeration site (Fig. 2).

Spawning gravel for the channel was selected on the basis of gravel composition in preferred natural spawning areas in the Adams and Okanagan Rivers and in Jones Creek (Hourston and MacKinnon 1956). A grading curve was established (MacKinnon et al. 1961) and gravel ranging in size from 6 mm to 38 mm was placed in the channel to a depth of approximately 30 cm to 46 cm. In 1973, larger gravel ranging in size from 19 mm to 102 mm was placed in the channel to increase porosity.

To prevent fish from entering the Jones Creek flood channel, a fish diversion structure, 70 m long, was constructed across the original stream bed (Figs. 2 and 3). One third of this structure paralleled the channel entrance and served as a barrier fence to direct fish into the channel, while the remainder was a low timber dam with an open spillway designed to pass flood flows. At the top end of the spawning channel, a removable fish barrier was installed to prevent fish from moving beyond the upper limits of the spawning channel.

The channel included two settling basins for trapping organic debris, suspended silt, and moving bedloads (Fig. 2). The first basin lies on the upstream side of the intake control valve and was originally a natural pool in the creek's main channel. Siltation problems persisted and in 1956 this pool was enlarged and a second basin, 30.5 m long and 0.6 m deep, was formed out of the uppermost channel section. In 1973, the second basin was lengthened to 61.0 m and deepened to 0.75 m, and invert controls were placed at the 30 m and 45 m points to reduce velocities.

The Jones Creek spawning channel was completed in September 1954, and became fully operational in 1955.

During the first year of channel operation severe bank erosion occurred, mainly due to spawner activity. Channel width increased from approximately 3 m to 4.6 m and channel banks became steep and undercut. The banks stabilized in

Fig. 3. Spillway and fish diversion fence at channel outlet (foreground) showing spillage from Jones Creek flood channel, spring 1982.

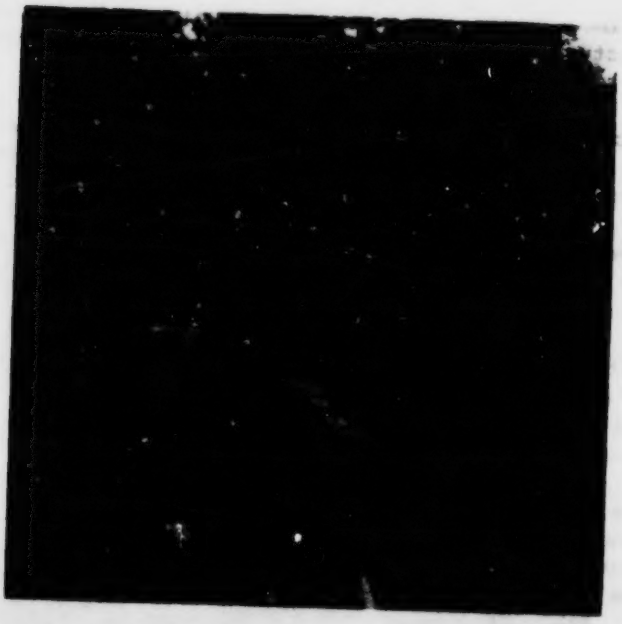


Fig. 4. Removal of silt, sand and gravel from Jones Creek settling basin No.1, fall 1981. Intake control valve is seen in the foreground.

the next few years with the regrowth of natural vegetation along the channel margins. Some bank erosion continued to occur as a result of freshet-related erosion, ice scouring, spawner activity, and gravel cleaning and replacement operations. However, channel width changed little due to restoration work and the width measured in 1983 averaged 4.9 m. The changes in channel dimensions are documented in Appendix 1. Despite the reduced channel length due to construction of settling basin No. 2, the available spawning area above the counting apron increased from 1954 to 1983 by approximately 36% (from 1756 m^2 to 2390m^2) (Append. 1).

CHANNEL OPERATION AND MAINTENANCE

The channel, since its construction, has been operated by DFO and maintained by B.C. Hydro and Power Authority, under DFO supervision. The channel is generally reconditioned in odd-cycle years just prior to the arrival of pink salmon in September. A major maintenance problem has been the heavy sedimentation of the channel gravel, and maintenance work consisted mainly of cleaning sediment from the channel and cleaning out the two settling basins (Append. 2). In earlier years, a small rubber-tired tractor with a rake blade was used to scarify the gravel; later, it was replaced by a caterpillar tractor with a back-hoe bucket. During seven years of the 13 odd-year cycles of pink runs into the channel, it was necessary to completely remove and replace, or screen and replace all or part of the channel gravel due to extreme sedimentation (Append. 2). In 1971 and 1973, all material finer than 6 mm was removed from the gravel.

Other maintenance work involved the repair and reconditioning of the fish-diversion structures in the creek and the lower end of the channel because the timbers have deteriorated with time.

The annual costs of the above maintenance work on the Jones Creek channel were minimal during the 1950's and 1960's, but have risen sharply since 1971 due to silting problems aggravated by logging operations (Append. 2). The construction costs of the Jones Creek channel per unit area and its biennual maintenance requirements are comparable to those observed for other facilities (Append. 3). Some of the maintenance activities on the Jones Creek channel, conducted in 1981, are shown in Figures 4 to 10.

The DFO operation of the channel includes the enumeration and biological sampling of fry and adults during the odd-numbered years, and periodic inspection of the channel during the winter incubation period. Winter maintenance may include cleaning of debris from the channel intake valve to ensure free flow of water, and breaking up of frazil ice. During the even-numbered years, the intake valve is shut off and the channel remains dry. While this approach prevents a small number of chum and coho adults from utilizing the channel every year, it substantially reduces channel siltation and related maintenance costs.

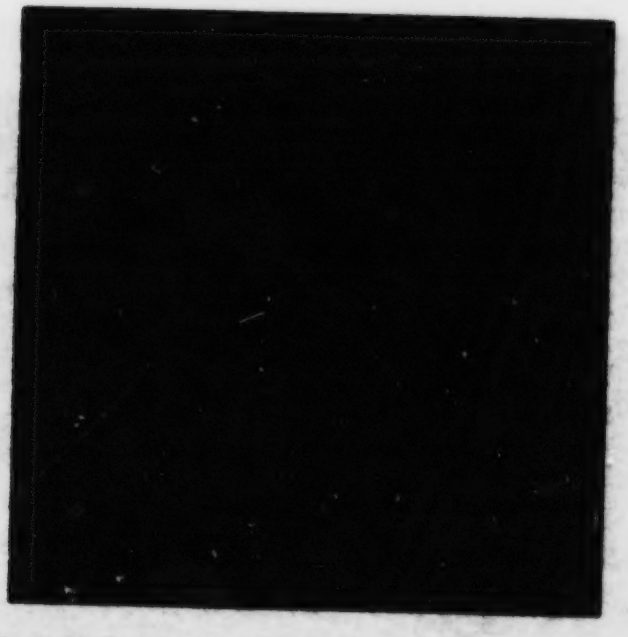


Fig. 5. Settling basin No.2 cleaned out and ready for new gravel, Jones Creek spawning channel, fall 1981. Note invert controls.

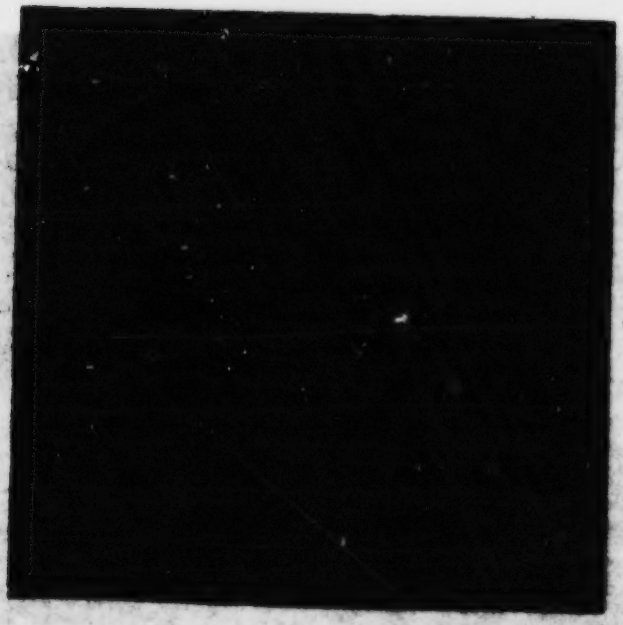


Fig. 6. Loading of silted gravel for removal from Jones Creek spawning channel, fall 1981.

Fig. 7. Placing and grading new gravel in Jones Creek spawning channel, fall 1981.

Fig. 8. Replaced gravel and retention invert with reinforcing rock rip-rap, Jones Creek spawning channel, fall 1981.

Fig. 9. New concrete flume for the fish counting fence in Jones Creek spawning channel, fall 1981 (looking downstream).

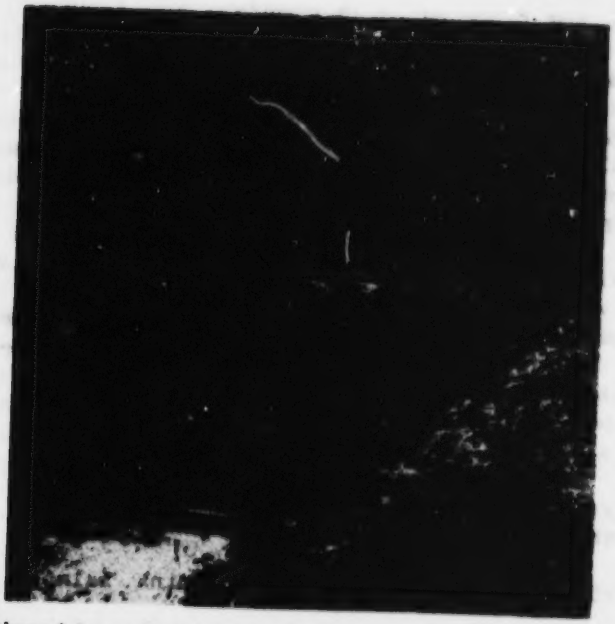


Fig. 10. Reconditioned Jones Creek spawning channel ready for spawners, fall 1981.

METHODS

ADULT ENUMERATION

Prior to 1949, escapement estimates into Jones Creek were obtained by Fishery Officers from periodic visual observations. In 1949, in preparation for the hydroelectric dam construction, the first thorough enumeration of Jones Creek spawners was conducted using tagging, and live and dead counts. In 1956, an adult counting fence was installed at the channel exit, and live counts and dead recovery were made throughout the pink spawning period above and also generally below the fence. Since that time, all salmon species were enumerated in odd-numbered years during the pink salmon run using the above method. Enumeration methods for each year since 1949 are summarized in Appendix 4.

Fence counts were made one to four times daily. Live counts in the channel (if no fence counts were taken) and dead recovery counts were generally made daily but less often below the fence depending on weather conditions. The removable enumeration facility consisted of a V-shaped fence that formed a pen allowing the holding of fish for sampling (Fig. 9). Due to flooding of the lower channel sections during high Fraser River water levels, the fence was originally installed (in 1957) approximately 30 m upstream from channel exit; in 1973 it was moved upstream another 6 m.

In some years the fence was installed but left open to allow a free passage of spawners into the channel while preventing the washout of carcasses. This approach served largely to reduce the stress on fish from holding at the fence. Daily live counts in each channel section and daily dead recovery provided escapement estimates.

In this report, all counts above the fence are referred to as channel counts and those below the fence as creek counts.

CALCULATION OF ESCAPEMENT ESTIMATES

Escapement estimates of pink and chum salmon into the Jones Creek channel were generally calculated from the available data as the maximum of three counts: 1) total fence count 2) total dead recovery and 3) live channel count on the last day of fence operation plus cumulative dead count. In years when no fence count was made, channel escapement estimates for pink and chum salmon were calculated as the maximum sum of daily live count plus cumulative dead.

Escapement estimates (E) for pink and chum salmon in Jones Creek below the fence were based on less complete data compared to the channel estimates and, where possible, were calculated as follows:

For pink salmon:

E = (peak daily live count + cumulative dead count) x 2.6 - (No. pink salmon that entered the channel after that date)

where 2.6 is the visual accuracy factor for pink salmon in small streams

determined from tagging surveys by the International Pacific Salmon Fisheries Commission (R. Kent, IPSFC, pers. comm.).

For chum salmon:

E = (maximum sum of daily live count + cumulative dead count).

No adjustment factor was available for chum salmon.

Data sources used for calculating pink and chum escapements in the channel and the creek for each brood year are shown in Appendices 5a and b.

SPAWNING DISTRIBUTION

Spawning distribution of pink salmon and less often of chum salmon in the Jones Creek spawning channel was obtained by visual count of spawners in each of the near-equal channel sections separated by invert controls (Fig. 2). Counts were taken at one to five day intervals throughout the migration period and whenever visibility was adequate. Counts per section, accummulated over equally spaced time intervals when possible, were converted to percent of total fish observed utilizing each section.

Prior to 1973, 18 channel sections were enumerated for spawner distribution. From 1973, only 16 sections were available (the top section was converted to a settling basin and the bottom section was "eliminated" - it was modified to facilitate fish entry into the channel and the counting fence was moved above it; Fig. 2).

ADULT SAMPLING

The biological sampling of pink and chum adults in the Jones Creek system was conducted throughout the pink spawning period. The annual sex composition from total dead recovery and periodic egg retentions were determined in odd-numbered years since 1955. From 1973, pink adult carcasses recovered on the spawning grounds were sampled for postorbital-hypural length ($\pm$1 mm), with up to 600 fish sampled each year in the channel and up to 175 in the creek. All measured females were also checked for egg retention. Sampling for pink fecundity occurred on only three occasions and the sample size ranged from 8 to 20 females.

Sampling of chum adults was generally carried out as for pink adults, except that chum females were not sacrificed for fecundity estimates due to the small size of the run. Those chum measured for length were also generally sampled for age; scale analysis was carried out in the DFO Vancouver scale laboratory. Very limited length and age sampling of coho adults was carried out. Only the channel sex ratio was utilized for all species since the creek sex ratio was biased due to the loss of carcasses and the straying of males away from the spawning grounds.

FRY ENUMERATION

All juveniles migrating out of the Jones Creeks spawning channel during the odd-year pink cycle were enumerated using a Wolfe-type inclined plane trap (Fig. 11). The Wolfe trap (3 m wide x 2 m long) was generally installed in the lower end of the channel at the adult fence site. Stoplogs were placed across the channel to create the required head for the Wolfe trap which emptied into live boxes. Fry collected in the live boxes were identified, counted and released downstream. Pink, chum and coho fry were enumerated concurrently at hourly to daily intervals, and individually or either volumetrically or gravimetrically depending on the size of the run. Usually four conversion samples were taken at each volume or weight counting. Pink, chum and coho fry were not separated during sampling, and the same conversion factor was used for the three species.

The trap was fished continuously, generally between late March and late May, and was usually removed when the total daily migration dropped to a few hundred juveniles per day. The trap was cleared of debris as required in order to maintain free flow. In some years, a debris boom was installed several meters upstream of the trap.

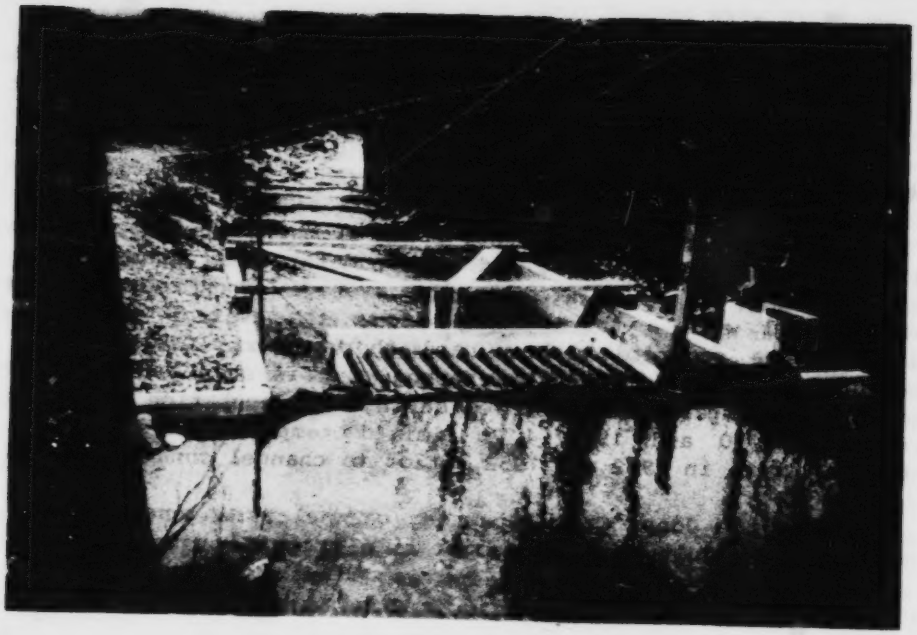
Fry production in the creek below the channel enumeration site was not monitored. Instead, an estimated mean egg-to-fry survival rate of 13% obtained for pink salmon spawning naturally in the Fraser River was applied to the estimated pink egg deposition below the channel enumeration site. Similarly, an estimated mean egg-to-fry survival rate of 9% obtained for chum salmon spawning naturally in the B.C. rivers was applied to the estimated chum egg deposition below the channel enumeration site. Both of the above survival estimates were obtained from the Salmonid Enhancement Program (SEP) design criteria (draft updated March 1982).

In 1972, the Wolfe trap was installed approximately 25 m above the adult fence site in order to reduce the chance of flooding the trap during the Fraser River spring freshet. To monitor the channel section below the Wolfe trap, a fyke net (0.3 m x 0.9 m) was installed just above the adult counting apron. The mean catchability of the fyke net was determined by making a total of four marked releases of pink fry upstream, immediately below the Wolfe trap.

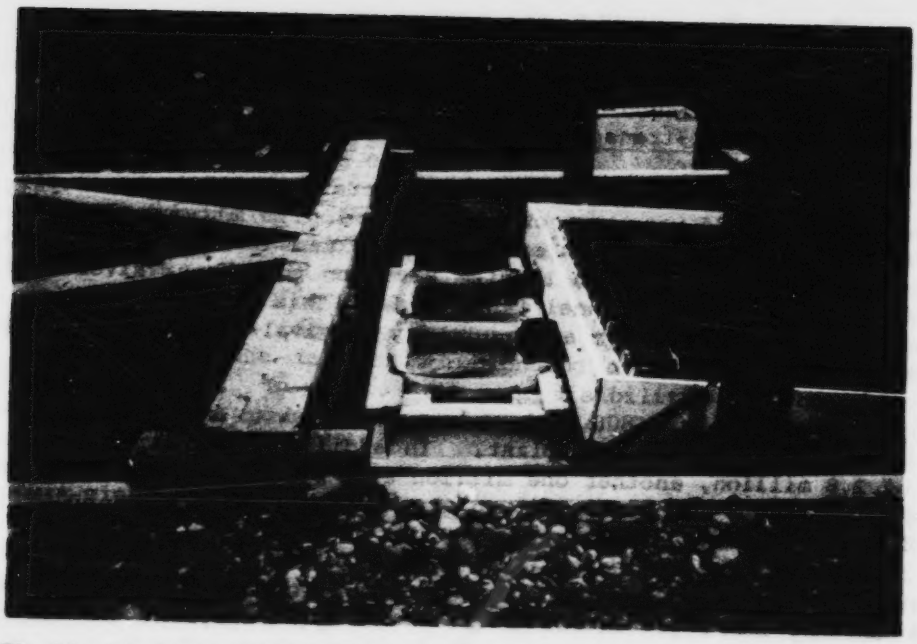
In 1974, two Wolfe traps were utilized; one was installed approximately 122 m from the top end of the channel and the other at the adult counting apron. This enumeration method served to compare the fry survival rates in the upper and lower channel sections.

FRY SAMPLING

Biological sampling of fry produced in the Jones Creek channel began in 1972 for pink and in 1976 for chum. Fry were generally sampled every few days to a week throughout the 10% to 90% of the run. Pink and chum juveniles were measured for nose-fork length (n=20-40; ±1 mm) and for individual wet weight (blotted dry; n = 20-40; ± 1 mg), but in 1982 fry were weighed in aggregate



(a)



(b)

Fig. 11. Fry enumeration in the Jones Creek spawning channel using a Wolfe trap, May 1982 (a – looking downstream; b – side view).

(n = 25-100; ±1 mg) in order to reduce injury and stress to the fish. Fry produced in the creek were not sampled.

Daily sample means of fry lengths and weights were averaged to estimate the annual mean; extrapolation of size means to daily migration totals was not done due to inconsistencies in sampling intervals.

PHYSICAL SAMPLING

Surface water temperature in the Jones Creek spawning channel was generally measured daily during the pink adult and fry enumeration programs. The daily mean water temperature was calculated as the average of minimum and maximum temperatures recorded with a thermograph, or as the average of morning and afternoon temperatures recorded with a hand thermometer. Temperatures were generally measured at the adult counting apron, but in some years also at the channel head. Water temperatures observed during egg incubation were monitored during 1967/68, 1969/70 and 1973/74. Limited temperature data were also obtained for Jones Creek in 1952 and 1953, prior to channel construction.

Water levels in the Jones Creek spawning channel were generally monitored daily during the pink adult and fry enumeration programs using a staff gauge located at the top end of the channel. The gauge was previously calibrated to show the range of expected flow levels.

Methods used for sampling gravel and oxygen in the channel in 1968 and for sampling gravel in 1973/74 are detailed in Appendices 11 and 12.

RESULTS AND DISCUSSION

PINK SALMON

Even-year pink experimental transplants

The first year of the Jones Creek channel operation (1954) was an off-cycle year for the existing odd-year run of pink salmon. An attempt was made that year to establish an "even-year" run and during October to November, 2.7 million pink salmon eggs were shipped from Lakelse River on the Skeena River system to be planted in the Jones Creek channel (Append. 6). This egg deposition produced an estimated 1.1 million fry with an egg-to-fry survival rate of 42.2% (Append. 6) (Neave and Wickett 1955).

In 1956, approximately 2,800 pink salmon returned to spawn in the channel as a result of the 1954 egg transplant. In addition to their estimated egg deposition of 2.8 million, another one million eyed eggs from Lakelse River were transplanted that year. However, due to severe winter conditions and silting, only 8.5% of the eggs survived to fry stage.

In 1958, only 39 pink salmon returned to spawn in the Jones Creek channel. These included the first generation of the 1956 egg transplant and the second generation of the 1954 egg transplant. No further attempts were made at that time to support the even-year pink run and it terminated naturally.

In 1972, the Pacific Environmental Institute and the DFO planted 24,000 pink salmon eggs in the channel. In 1974, pink adults were observed to return to Jones Creek from this plant (E. Donaldson, pers. comm.), but the experiment was terminated for stock management reasons.

Compared to the above egg-to-fry survival at the Jones Creek channel, tranplants of pink salmon eggs elsewhere in B.C. since that time had varying degrees of success. A large scale transplant in 1959 of pink salmon eggs from the Tsolum River to the Robertson Creek spawning channel produced an egg-to-fry survival of almost 95% (MacKinnon 1960). The features found at the Robertson Creek spawning channel which may account for the high survival of tranplanted eggs compared to the Jones Creek channel were clean, larger-sized gravel, cleaner water and more moderate winter conditions. In 1963 and 1964, eyed pink eggs totalling 11.6 million were transplanted from Cheakamus and Bear Rivers into the Big Qualicum River channel No. 1. Their low survival rate of 39% (Walker and Lister 1971) was believed to be due to extensive sedimentation in the incubation channel.

Pink escapement

During the 1934 to 1953 period, before the operation of the Wahleach hydroelectric project and prior to spawning channel construction, the annual odd-year pink escapement to Jones Creek averaged 4,250 fish (Table 1). From 1954 to 1981, the odd-year pink escapement to the channel and Jones Creek averaged 2,882 fish or around 70% of the pre-channel population size, with approximately 75% of the total pink returns spawning in the channel (Table 1). After the very low return of pink salmon in 1955, the population of pink adults spawning in the channel ranged from 1,056 in 1957 to 4,388 in 1961 (Table 1).

Comparison of the pink escapement estimates for the Jones Creek system before and after channel construction is biased by the more accurate enumeration of spawners after 1954 when regular visual counts and dead recovery were conducted. This was especially true of the channel counts which were facilitated by the use of the counting fence.

Spawner enumeration in the channel was at times hampered by poor visibility due to suspended sediments and heavy rains. This resulted in discrepancy between the live and dead counts. Likewise, enumeration of spawners in the creek below the channel was hampered by turbid and discoloured water making visual counts and dead recovery difficult. Spawner counts in the creek were also underestimated due to periodic flooding of the Fraser River and loss of carcasses downstream. To correct for poor visibility, pink counts in the creek were adjusted, where possible, by a factor of 2.6 derived by the IPSFC (see methods).

Pink adult migration timing and spawning distribution

For the nine years on record (Table 2), pink adults generally migrated past the fence into the Jones Creek spawning channel during a period of approximately 34 days from around mid-September to mid-October; however, over 90% of the

Table 2. Pink adult migration timing and dead recovery in Jones Creek spawning channel, 1957 - 1981.

Year	Period of fence operation	Period of migration through fence[a]	Duration of migration[a] (days)	50% Fence migration	50% Dead recovery[b]	Period of channel residence (days)[c]
1955	NO FENCE	-				
1957	Sept. 10 - Oct. 24	Sept. 11 - Oct. 15	35	Sept. 24	-	-
1959	Sept. 10 - Oct. 8	Sept. 11 - Oct. 12[d]	32	Sept. 27	-	-
1961	Sept. 8 - Oct. 20	Sept. 15 - Oct. 17	33	Sept. 23	-	-
1963	N/A[e]	-	-	-	-	-
1965	N/A[e]	-	-	-	-	-
1967	Sept. 13 - Oct. 30	Sept. 13 - Oct. 29	47	Sept. 29	Oct. 13	15
1969	Sept. 16 - Nov. 2	Sept. 16 - Oct. 30	45	Sept. 28	Oct. 11	14
1971	N/A	-	-	-	-	-
1973	Sept. 19 - Oct. 21	Sept. 20 - Oct. 21	31	Oct. 1	Oct. 13	13
1975	Sept. 21 - Oct. 21	Sept. 22 - Oct. 16	25	Sept. 30	-	-
1977	Sept. 16 - Oct. 18	Sept. 19 - Oct. 16	28	Sept. 26	Oct. 11	16
1979	Sept. 16 - Oct. 19	Sept. 18 - Oct. 17	30	Sept. 27	Oct. 10	14
1981	N/A[e]	-	-	-	-	-
Mean ±1S.E. (days)	-	-	34.0 ± 2.5	Sept. 27±0.9	Oct. 12±0.6	14.4±0.5

[a] Interval between first and last pink counts through fence.

[b] Given only where total dead recovery was within 90% or more of total fence count.

[c] Difference between 50% fence migration and 50% dead recovery in channel.

[d] Additional fish were observed to enter after fence was pulled.

[e] Not applicable; fence installed but no counts made.

migrants entered during a period of only 20 days (Fig. 12). The 50% completion date for migration past the fence averaged September 27 (range September 23 - October 1; Table 2). Pink spawning mortality in the channel occurred approximately 14 days after channel entry, as indicated by the difference between 50% migration timing and 50% dead recovery (Table 2). A similar mean interval of 14 days was observed between peak migration and peak dead recovery (Append. 7). Peak spawning of pink salmon in the Jones Creek channel occurred on the average at the end of September, or one to two weeks earlier than that of most other Fraser River pink stocks (early to mid-October) (IPSFC 1982).

Both day and night migrations were observed. In 1975, migration and spawning activity increased in the late evening when the relatively high water temperatures (Append. 19f) declined. In some years, the start of pink migration into the channel was delayed by a week or more due to prolonged maintenance activities and a later opening of the channel, and due to difficulty by adults to negotiate the steep channel entrance prior to the 1973 modifications.

Water temperatures during pink adult migration into the channel generally declined from around 12°C in mid-September to around 10°C by mid-October (Fig. 21, Table 17).

The first observations on pink spawning distribution in the Jones Creek channel were made in 1955 (Hourston and MacKinnon 1956). Briefly, the study showed that the early arriving pink salmon chose the uppermost spawning areas while subsequent arrivals spawned immediately behind them. Spawner distribution was influenced largely by water depth and velocity. Fast (0.9 m/sec) and shallow (30 cm) areas prevalent in the lower channel sections were almost completely avoided by spawning fish, and both pink and chum salmon preferr[illegible] lower velocity and slightly greater depth. Spawners also preferred areas with cover provided by the relatively turbulent water at the intake and below each invert control. Therefore, in the first year of channel operation, spawning distribution was relatively localized with adults crowded near the turbulent areas. With the regrowth of vegetation along the channel banks, more fish began to utilize the mid-stream channel sections.

Mean spawning distribution of pink salmon in the Jones Creek channel from 1965 to 1971 and from 1973 to 1981 when the number of sections was reduced (see methods) is shown in Figure 13 and Appendix 8. Since the channel sections are near equal in length (~ 30 m), the proportion of spawners in each section should reflect fish density. Averaged over the period of study, the distribution of pink salmon was relatively uniform throughout the channel, with approximately 5% to 7% of spawners utilizing each section (Fig. 13). Greatest fish concentrations were observed in the uppermost channel section where early and peak spawners held. Spawning density decreased along the channel as crowding and adult interactions forced individuals to move downstream, and new arrivals spawned in the lower channel sections. The overall increase in spawner density in the lowest channel sections (1973-1981 data) is characteristic of adults which enter late in the migration and spawn soon after moving into the spawning grounds. This density increase may also be related to the spent fish drifting from the upper channel sections. Such increase was not apparent in the pre-1973 data probably due to the smaller area (by about 30%) of the last

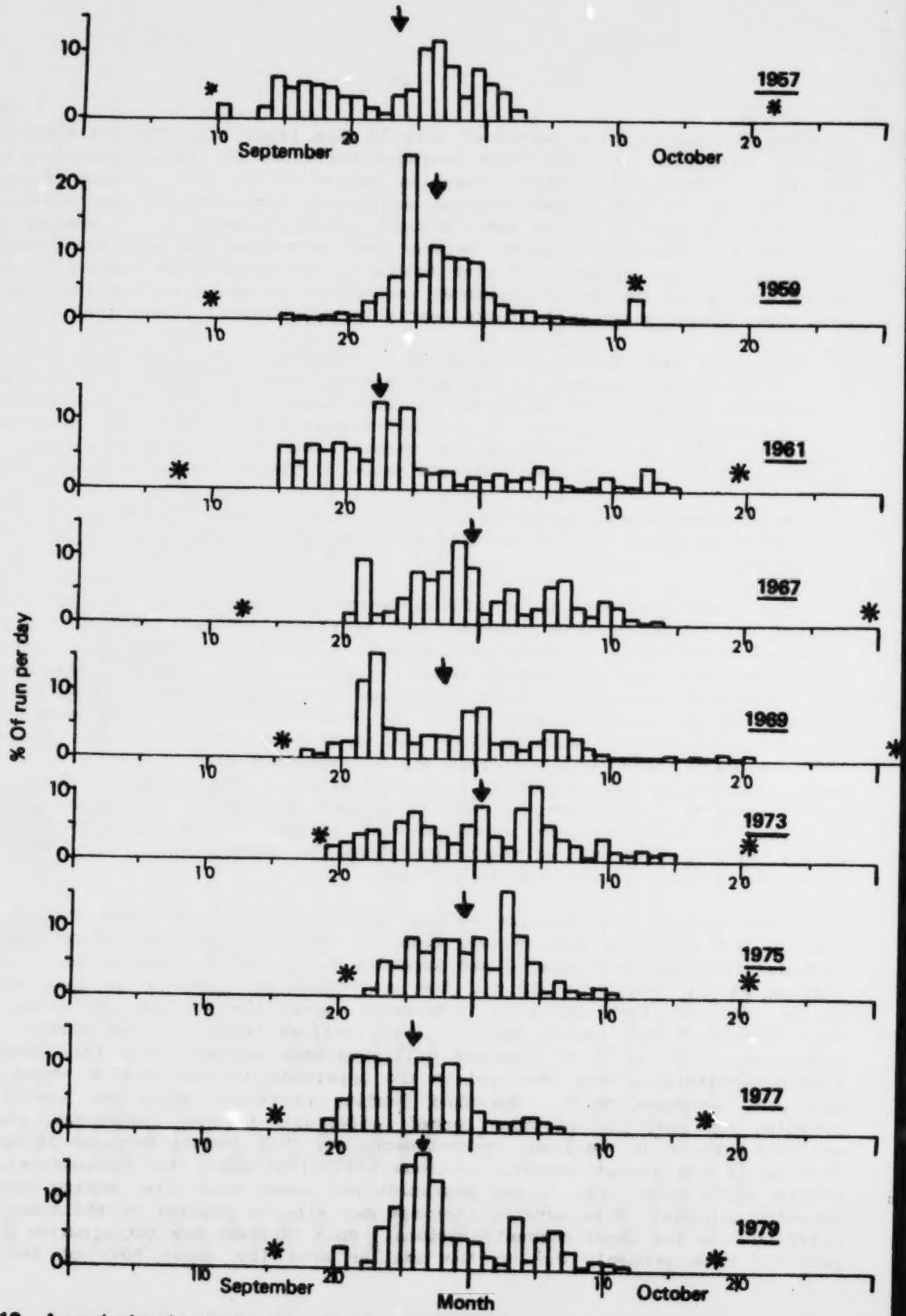


Fig. 12. Annual migration timing of adult pink salmon into Jones Creek spawning channel, 1957 – 1979 (asterisks indicate start and end of enumeration; arrows indicate 50% completion of counts).

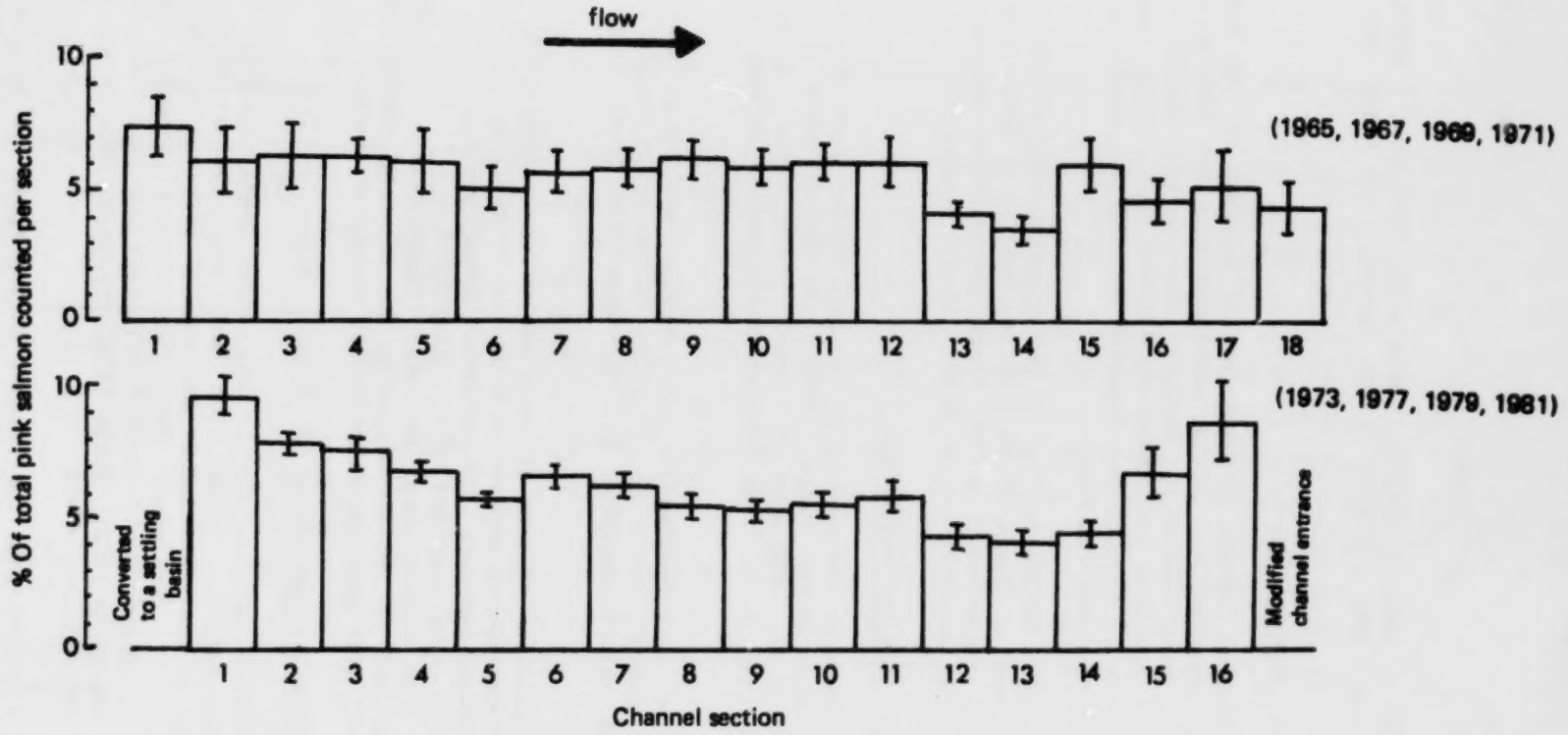


Fig. 13. Mean pink salmon spawning distribution in Jones Creek channel, 1965 – 1981 (see Fig. 2 for location of channel sections; vertical bars indicate ± 1 S.E.).

channel section compared to that of others. Generally, less than a dozen fish spawned in the relatively steep entrance to the channel just below the adult counting apron.

Pink adult length and sex composition

Mean postorbital-hypural length of pink adults sampled in the spawning channel and Jones Creek averaged 44.1 cm for males and 42.7 for females (Table 3). Although females were generally smaller than males, annual length differences between the sexes were not always significant ($p < 0.05$). Also, no significant size difference ($p < 0.05$) was observed between pink adults sampled in the channel and in Jones Creek (Table 3).

Sex composition of pink adults sampled in the spawning channel during 1955 to 1981 averaged 55.3% females (range 46.6% - 63.7%; Table 4). This is similar to the pink female sex composition in the Upper Seton Creek channel which averaged 59.3% between 1961 and 1975 (range 49.5% - 65.4%) (Cooper 1977).

Pink fecundity, egg retention and deposition

Fecundity of pink females was available for only three years and averaged 1,829 eggs per female (mean annual range 1,693 - 1,961 eggs; Table 4, Append. 9). Comparable fecundity of 1,882 eggs per female (range 1,764 - 2,065 eggs) was observed among the Upper Seton Creek channel pink spawners between 1961 and 1975 (Cooper 1977).

Spawning success of pink females (actual/potential egg deposition) x 100 averaged 95.8% in the channel (Table 4) and 95.0% in the creek (Table 5), and was comparable to the values reported for the Upper and Lower Seton Creek channels (Cooper 1977).

The actual egg deposition of pink spawners was determined by adjusting the total potential egg deposition as derived from fecundity data, by egg retention and proportion of unspawned females. The estimated actual egg deposition in the channel averaged 2.04 million eggs per year (range 0.44 - 3.97 million; Table 4), and in the creek 0.81 million eggs per year (range 0.39 - 1.51 million; Table 5). During the 1955 to 1981 brood years, the spawning channel received approximately 72% of all pink eggs deposited in the creek and channel.

Pink fry production and migration timing

The annual production of pink fry in the Jones Creek spawning channel averaged 747,800 (range 145,700 - 1,574,000; Table 4). The estimated annual production of pink fry in the creek below the channel averaged 105,300 (range 50,700 - 196,300) (Table 5). Fry production in the channel increased from less than 0.2 million in 1956 to over 1 million in 1962, 1964 and 1966; then declined to less than 0.5 million up to 1972. Since 1976, fry production in the channel has varied around the one million level.

Pink fry usually migrated from the channel during April and May, with the run 50% completed on May 3 (range April 10 - May 23; Fig. 14, Table 6).

Table 3. Mean postorbital-hypural length (L± 1S.E) of adult pink males and females in spawning channel and Jones Creek, 1973 - 1981 (n given sample size).

Year	CHANNEL				CREEK				CHANNEL & CREEK			
	Male		Female		Male		Female		Male		Female	
	(n)	L	(n)	L	(n)	L	(n)	L	(n)	L	(n)	L
1973	(300)	43.0 ± 0.2	(302)	43.0 ± 0.2	(99)	45.4 ± 0.3	(65)	42.4 ± 0.3	(399)	43.6 ± 0.2	(367)	42.9 ± 0.1
1975	(105)	45.1 ± 0.3	(148)	43.7 ± 0.2	[a]		-		(105)	45.1 ± 0.3	(148)	43.7 ± 0.2
1977	(90)	43.4 ± 0.3	(88)	41.8 ± 0.3	(11)	43.4 ± 1.2	(12)	42.2 ± 0.5	(101)	43.4 ± 0.8	(100)	41.8 ± 0.5
1979	(100)	44.1 ± 0.3	(175)	42.7 ± 0.2	(75)	43.4 ± 0.3	(100)	42.3 ± 0.3	(175)	43.8 ± 0.2	(175)	42.6 ± 0.4
1981	(93)	44.4 ± 0.3	(89)	42.7 ± 0.2	-		-		(93)	44.4 ± 0.3	(89)	42.7 ± 0.2
Mean		44.0 ± 0.4		42.7 ± 0.3		44.1 ± 0.7		42.3 ± 0.1		44.1 ± 0.3		42.7 ± 0.3

[a] Not sampled.

Table 4. Pink adult escapement, egg deposition and fry production in Jones Creek spawning channel, 1955 - 1981 brood years.

Brood year	No. spawners[a]	No. Females	% Females[b]	Fecundity[c] (eggs/female)	% Spawning success[c]	Actual egg deposition (X 1,000,000)[d]	Estimated fry migration (X 1,000)	Egg-to-fry survival (%)
1955	400	252	63.0	1,829	95.8	0.44	158.4	36.0
1956	2,800	1,588	56.7	1,829	95.8	3.78[e]	321.0	8.5
1957	1,056	647	61.3	1,829	95.8	1.13	364.6	32.3
1959	2,119	1,085	51.2	1,829	96.7	1.92	958.6	49.9
1961	4,388	2,308	52.6	1,829	94.1	3.97	1,055.2	26.6
1963	2,806	1,714	61.1	1,829	95.8	3.00	1,055.4	35.2
1965	2,146	1,367	63.7	1,829	95.8	2.40	1,267.8	52.8
1967	2,874	1,460	50.8	1,829	93.5	2.50	281.0	11.2
1969	1,319	615	46.6	1,829	98.1	1.10	145.7	13.2
1971	1,194	675	56.5	1,829	95.8	1.18	420.8	35.7
1973	1,851	1,011	54.6	1,693	98.0	1.68	593.7	35.3
1975	2,046	1,027	50.2	1,829	95.7	1.80	1,151.2	64.0
1977	1,911	1,005	52.6	1,961	95.1	1.87	943.9	50.5
1979	3,567	1,662	46.6	1,834	93.3	2.84	924.8	32.6
1981	1,810	1,113	61.5	1,829	97.9	1.99	1,574.9[f]	79.1
Mean	2,153	1,169	55.3±1.5 (± 1S.E)	1,829	95.8	2.04	747.8	37.7±4.9

[a] See Append. 5a for details.
[b] From dead recovery data (Append. 5a).
[c] See Append. 9 for details.
[d] Potential egg deposition corrected for spawning success.
[e] Includes one million transplanted eggs.
[f] But only 1,572,400 live fry due to trapping mortality.

Table 5. Pink adult escapement, egg deposition and fry production in Jones Creek, 1955 - 1981 brood years.

Brood year	No. spawners[a]	% Females[b]	No. females	Fecundity[c] (eggs/female)	% Spawning success[d]	Actual egg deposition[e] (X 1,000,000)	Estimated fry migration[f] (x 1,000)	Egg-to-fry survival (%)[f]
1955	-[g]	63.0	-	1,829	95.0	-	-	-
1956	-	56.7	-	1,829	95.0	-	-	13
1957	962	61.3	590	1,829	95.0	1.03	133.9	13
1959	455	51.2	233	1,829	95.0	0.40	52.0	13
1961	769	52.6	404	1,829	95.0	0.70	91.0	13
1963	700	61.1	428	1,829	95.0	0.74	96.2	13
1965	782	63.7	498	1,829	95.0	0.87	113.1	13
1967	869	50.8	441	1,829	94.3	0.76	98.8	13
1969	488	46.6	227	1,829	95.0	0.39	50.7	13
1971	629	56.5	355	1,829	95.0	0.62	80.6	13
1973	1,162	54.6	634	1,693	96.9	1.04	135.2	13
1975	620	50.2	311	1,829	95.0	0.54	70.2	13
1977	1,363	52.6	717	1,961	96.5	1.36	176.8	13
1979	723	46.6	337	1,834	92.5	0.57	74.1	13
1981	1,417	61.5	871	1,829	95.0	1.51	196.3	13
Mean	841	55.3±1.5 (± 1S.E)	465	1,829	95.0	0.81	105.3	13

[a] See Append. 5b for details.
[b] Using corresponding channel sex composition.
[c] Using corresponding channel fecundity.
[d] See Append. 9 for details.
[e] Potential egg deposition corrected for spawning success.
[f] Derived by applying mean natural egg-to-fry survival for Fraser River pink salmon (13%)(from SEP design criteria, 1982 draft).
[g] No data.

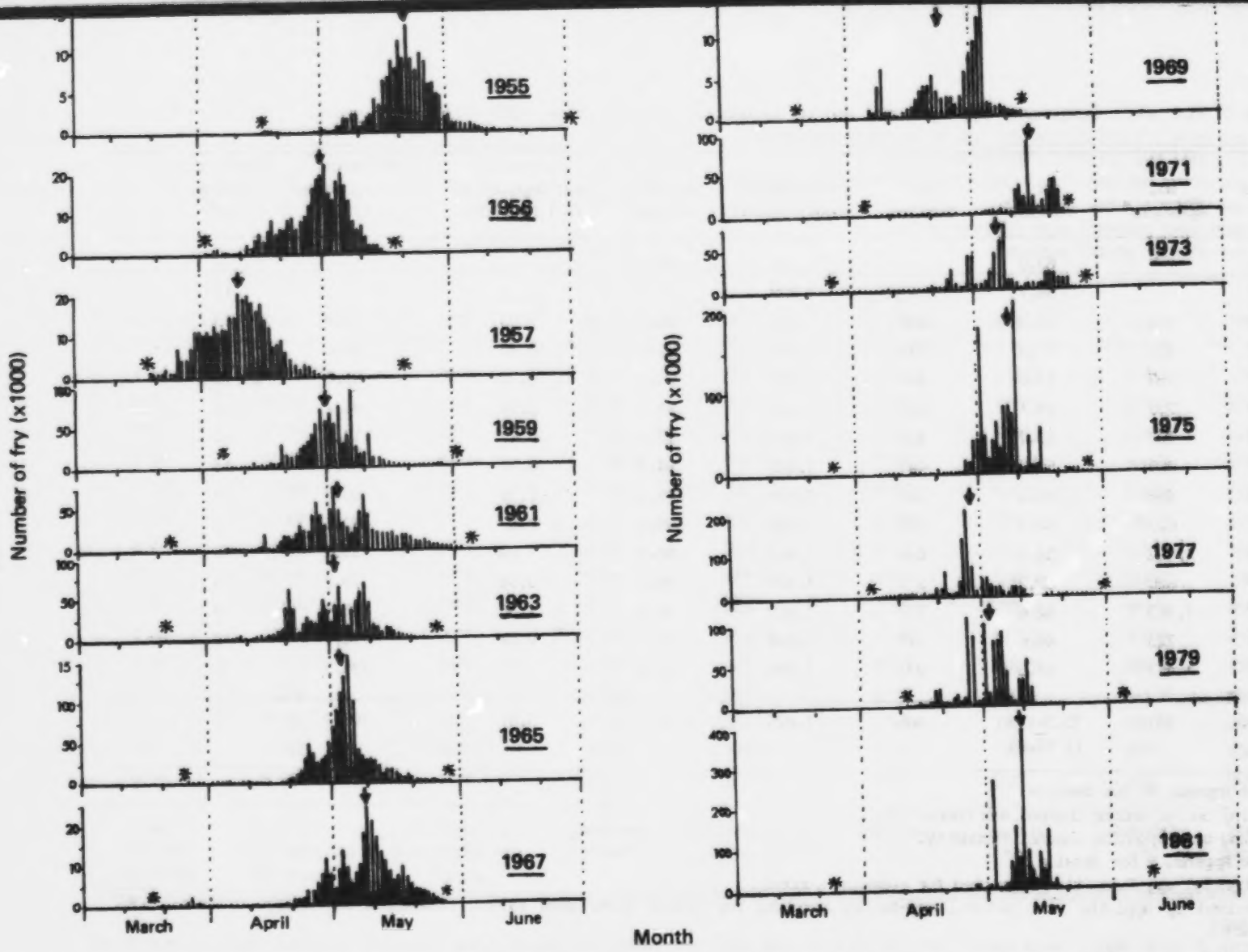


Fig. 14. Annual migration timing of pink fry from Jones Creek spawning channel, 1955 – 1981 brood years (asterisks indicate start and end of enumeration; arrows indicate 50% completion of counts).

Table 6. Pink fry enumeration and migration timing into Jones Creek spawning channel, 1954 - 1981 broods.

Brood year	Enumeration Period	No. fry (X 1,000)	Migration timing		
			Duration period[a]	Duration (days)[a]	50% of Total count
1954	April 2 - May 17	901.4	April 2 - May 17	46	May 1
1955	April 17 - June 12	158.4	April 18 - June 12	56	May 21
1956	April 2 - May 18	321.0	April 2 - May 17	46	April 30
1957	March 19 - May 23	364.6[b]	March 19 - May 9[b]	52[b]	April 10
1959	April 6 - June 2	958.6[b]	April 6 - June 2[b]	58[b]	May 1
1961	March 24 - June 5	1,055.2	March 24 - June 5	74	May 3
1963	March 22 - May 27	1,055.4[b]	March 22 - May 27[b]	67[b]	May 2
1965	March 26 - May 29	1,267.8[b]	March 26 - May 29[b]	65[b]	May 3
1967	March 17 - May 27	281.0[b]	March 24 - May 27[b]	65[b]	May 8
1969	March 19 - May 13	145.7[b]	March 21 - May 13[b]	54[b]	April 23
1971	April 5 - May 23	420.8[b],[c]	April 5 - May 28[b],[c]	54[b],[c]	May 15
1973	March 26 - May 29	593.7[b]	March 27 - May 28 [b]	63[b]	May 6
1975	March 26 - May 27	1,151.2[b],[d]	April 5 - May 30[b],[d]	56[b],[d]	May 8
1977	April 4 - May 30	943.9	April 5 - May 24	50	April 28
1979	April 12 - June 4	924.8[b]	April 12 - May 29[b]	48[b]	May 3
1981	March 24 - June 10	1,574.9[e]	April 9 - June 10	63	May 9
Mean (± 1S.E)	-	747.8[f]	March 31 - May 28[g]	59±2[g]	May 3±3[g]

[a] Where first and last day's count each exceeds 50 fry.
[b] Size of run slightly underestimated and duration of run probably underestimated by a few days since some 500 to 1,000 fry still migrated each day on first or last day of count.
[c] Includes Wolfe trap and fyke net catches (395,835 fry) + additional 25,000 fry estimated to migrate after trap removal (5,187 fry still migrated on last day of count; estimated duration of run extended by 5 days to account for end of run).
[d] Includes additional 5,000 fry estimated to migrate after trap removal (1,730 fry still migrated on last day of count; estimated duration of run extended by 3 days to account for end of run).
[e] Only 1,572,400 live fry due to trapping mortality of 2,493 fry.
[f] Excludes 1954 brood (from egg transplants).
[g] Excludes 1954 (total egg transplant) and 1956 (partial egg transplant) broods.

Duration of the downstream run averaged 59 days (range 48-74 days; Table 6). The above timing estimates were biased by the fry enumeration period.

Pink fry migrated from the channel largely after dusk, but daytime migration also occurred associated with high creek flows and turbid water conditions such as in 1976. These creek conditions were also often observed during peak fry migration.

Water temperature during pink fry migration from the channel increased from around 5°C in April to around 8°C by end of May (Fig. 21, Table 17). The relatively early migration timing of the 1957 and 1969 brood pink fry (Fig. 14) was probably related to the relatively high spring water temperatures observed for those runs (Append. 19b & d).

Compared to the odd-year Fraser River pink fry sampled at Mission between 1965 and 1977 (DFO, unpublished data), the 50% migration timing of pink fry in the Jones Creek channel occurred approximately one week later (May 3 vs April 26), despite the earlier spawning timing of the Jones Creek pink salmon.

The production of pink fry in the channel probably was underestimated in most years by around 5% mainly because the enumeration program often missed the start or end of the run. In several years, over 500 pink fry migrated on first or last day of fry enumeration period (Table 6). The number of pink fry was also underestimated in some years due to undermining of the Wolfe trap and construction of beaver dams (e.g. 1978). However, these two latter factors were considered to be insignificant and were not considered in the fry production estimates.

The production of pink fry in the creek below the channel was determined indirectly and was affected both by the spawner estimates used to calculate egg deposition, and the use of a standard egg-to-fry survival rate of 13% (see methods). Fry production in the creek was probably considerably underestimated in years when spawner counts were incomplete.

Pink fry size

Lengths and weights of pink fry migrating from the Jones Creek channel averaged 35.1 mm and 226 mg respectively (Table 7). These values were similar to the mean values of 33.6 mm and 267 mg reported for the 1961 to 1981 brood Fraser River wild pink fry sampled at Mission (Table 7; IPSFC, unpublished data).

Pink egg-to-fry survival

The annual egg-to-fry survival of pink salmon in the Jones Creek channel, based on the actual egg deposition and fry production estimates, averaged 37.7% (range 8.5% - 79.1%; Fig. 15, Table 4). These survival rates may be somewhat conservative since the annual fry production was underestimated by up to 5%. However, it is assumed that the errors in estimates of egg deposition and fry production tended to cancel each other.

Table 7. Mean length (L) and weight (W) of pink fry in Jones Creek spawning channel for 1971 - 1981 odd-year broods, and overall mean size of pink fry in Fraser River at Mission for 1961 - 1981 odd-year broods.

Brood year	Sampling Period	Mean length (± 1S.E.) No. fish	No. samples	L(mm)	Mean weight (± 1S.E.) No. fish	No. samples	W(mg)
		JONES CREEK CHANNEL					
1971	May 10 - 17	120	3	35.2[a]	120	3	219[a]
1973	April 18 - May 8	261	13	35.5±0.2	261	13	225±3
1975	April 29 - May 16	99	5	35.4±0.3	99	5	224±2
1977	April 21 - May 11	300	9	34.7±0.3	300	9	224±3
1979	April 21 - May 12	140	7	35.2±0.3	140	7	236±17
1981	April 29 - May 23	250	10	34.6±0.3	850	14	274[b]±6
Mean[c] ± 1S.E.	-	-	-	35.1±0.2	-	-	226±3[d]
		FRASER RIVER AT MISSION					
1961-1981 Mean[c]±1S.E.	-	-	-	33.6±0.1	-	-	267±6

[a] Raw data not available for statistical analysis.

[b] Comparatively heavier due to sampling technique since water was not sufficiently drained from fry prior to weighing.

[c] Mean of annual means.

[d] Excludes 1981 brood weight.

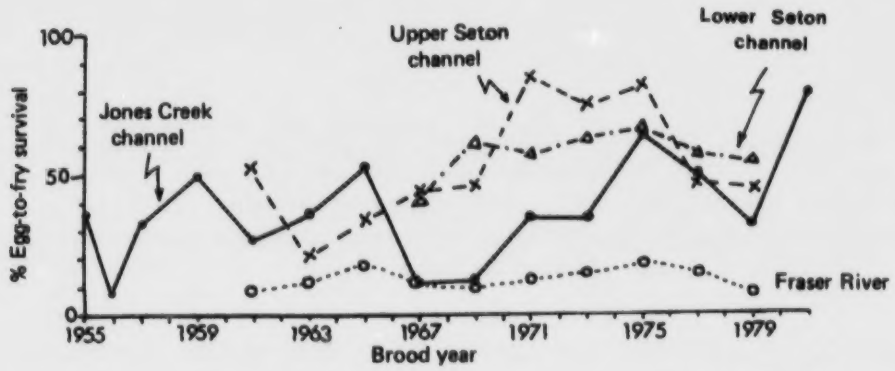


Fig. 15. Pink egg-to-fry survival rates by brood year in Jones Creek spawning channel, Upper and Lower Seton Creek spawning channels, and Fraser River for 1955 – 1981 brood years where available (see Append. 10 for sources of data).

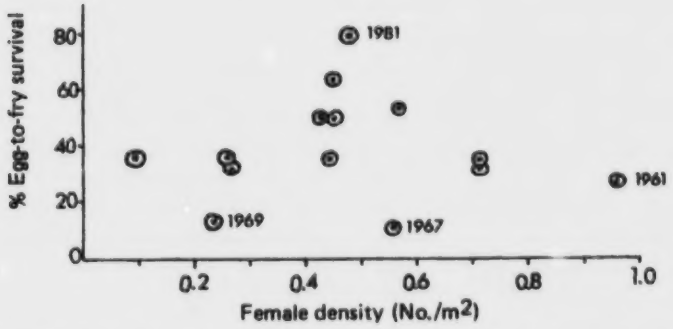


Fig. 16. Pink egg-to-fry survival related to density of pink female spawners in Jones Creek spawning channel, 1955 – 1981 brood years.

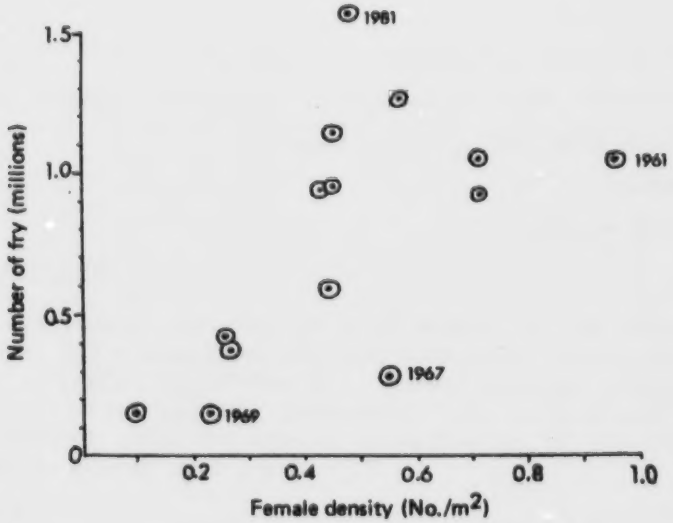


Fig. 17. Pink fry production related to density of pink female spawners in Jones Creek spawning channel, 1955 – 1981 brood years.

The above mean pink survival rate indicates that the channel is more successful than natural rivers where egg-to-fry survival can range from 1% to 23% and average 11% (Hourston and MacKinnon 1956). The survival of the Fraser River wild pink fry from the 1961 to 1979 broods averaged only 13.2% (Fig. 15, Append. 10). However, the mean survival in the Jones Creek channel was considerably lower than the mean pink survival rates of 53.5% and 57.4% reported for the Upper and Lower Seton Creek channels respectively (Fig. 15, Append. 10).

Several factors help explain the difference in survival between the Jones Creek and Seton Creek channels. The major factor may be sedimentation levels. The sediment is considered to be one of the greatest sources of mortality to incubating salmon eggs as it builds up within the gravel, resulting in poor water circulation which lowers the dissolved oxygen supply to sub-lethal levels; the presence of fine silt within the gravel may also interfere with or prevent fry emergence (Burrows 1964; Wells and McNeil 1970).

The Seton Creek channels are located just below Seton Lake in the semi-arid region near Lillooet. The water flowing into the channels contains few suspended solids and because the surrounding vegetation is sparse with few trees, there is little contamination of the gravel from the streamside foliage which may fall into the channel (Cooper 1977). In addition, the banks of the Seton Creek channels are lined with large rocks and cobble stones to reduce bank erosion. Silt generated in these channels is therefore reduced to a minimum.

By comparison, sediment is a serious and persistent problem in the Jones Creek spawning channel and, combined with occasional icing and scouring, is the major reason for the low egg-to-fry survival rates observed there (icing and scouring were related to the very poor survival rates of 9%, 11% and 13% observed for the 1956, 1967 and 1969 broods respectively).

Studies in the Jones Creek channel confirm the detrimental effects of sedimentation. Gravel and oxygen sampling conducted in May of 1968 revealed relatively high silt content in many locations, low subgravel oxygen levels at some sites, and the presence of dead advanced alevins in the gravel (Append. 11). A low egg-to-fry survival rate of 11% was observed for that brood year.

Gravel and hydraulic sampling, and fry enumeration conducted in the channel in 1973 to 1974, showed that the degree of siltation was directly related to pink egg and alevin survival (Append. 12). The study also showed that sedimentation was heaviest and egg losses greatest in the uppermost channel sections. The tendency for sedimentation to be most severe in the upper end of the channel was also evident in the Big Qualicum River spawning channels No. 1 and No. 2 (Fraser et al. 1983) and in the Abernathy channel in Washington (Thomas and Shelton 1968).

The suspension of logging in the Jones Creek watershed from 1979 to the mid-1980's may result in significant reduction in sedimentation of the channel and consequent increase in egg-to-fry survival.

Comparison of egg-to-fry survival rates and fry production in the Jones Creek channel to female spawner density indicated that both survival and fry

production were highest at a density of approximately 0.5 females/m^2 (Figs. 16 & 17); a similar result is obtained even when the relatively minor chum spawner component is added (Append. 13). By contrast, some of the highest egg-to-fry survival rates and fry production totals were recorded at a much higher pink spawner density of 1.1 females/m^2 in the Upper Seton Creek channel (Cooper 1977). The above comparison, however, is tenuous since the effects of female spawner densities in excess of 1.0/m^2 on egg-to-fry survival are not documented for the Jones Creek channel.

Spawning density in the Jones Creek channel was originally calculated on the basis of the 1949 escapement of 6,300 adult pink salmon (Hourston et al. 1956). At a 50% female sex ratio and 1800 m^2 of spawning area estimated to be originally available in the channel, a spawner density of 1.8 females/m^2 was anticipated. Using the present apparent calculated optimum of 0.5 females/m^2 and an available spawning area of 2400 m^2 (Append. 1), 1,200 pink females should use the channel to optimize the egg-to-fry survival and fry production. Using a mean male/female sex ratio of 45/55 (Table 4), the optimal number of males is 980, giving a total of 2,180 pink spawners that should utilize the channel to optimize fry production.

Commercial exploitation and total production of adult pink salmon

The Fraser River pink salmon stocks are managed by the International Pacific Salmon Fisheries Commission. Because of the extensive range in populaton size among the individual stocks, only the largest pink runs are regulated with some intensity. The smaller runs such as the Jones Creek are harvested incidentally, regardless of their strength.

The commercial catch of the Jones Creek pink salmon run was estimated indirectly by applying to the Jones Creek annual escapement estimate the corresponding annual catch/escapement ratio for the Fraser River pink salmon. The mean Fraser River catch/escapement ratio for the 12 odd-year cycle years from 1959 to 1981 (earlier data are not available) averaged 2.8:1 (Append. 14).

Using the above calculation method, the annual commercial catch of Jones Creek pink salmon averaged 6,400 fish for the channel and 2,400 fish for the creek (Table 8). The annual total adult production (catch plus escapement) to the combined creek and channel averaged 11,900 fish (range 4,500 to 26,300), with approximately 73% of the total production originating from the spawning channel (Table 8).

The above calculation method may underestimate the total pink salmon catch and return to the Jones Creek system because the catch proportion is probably higher than that for the Fraser River. This is because the relatively small Jones Creek pink salmon run returns to the Fraser River with the lower Adams River sockeye run, when the fishing pressure is most intense.

Pink marine survival

Fry-to-adult survival rates for the Jones Creek system (creek plus channel) were estimated by comparing the calculated downstream fry totals with the

Table 8. Calculation of the total pink salmon returns to Jones Creek and the spawning channel, 1959 - 1981 broods.

Year	JONES CREEK			SPAWNING CHANNEL			CREEK & CHANNEL	
	Total escapement	Calculated catch[a]	Total return	Total escapement	Calculated catch[a]	Total return	Total return	Channel return (% of total)
1959	455	2,271	2,726	2,119	10,578	12,697	15,423	82.3
1961	769	560	1,329	4,388	3,194	7,582	8,911	85.1
1963	700	1,209	1,909	2,806	4,846	7,652	9,561	80.0
1965	782	709	1,491	2,147	1,947	4,094	5,585	73.3
1967	869	5,230	6,099	2,874	17,296	20,170	26,269	76.8
1969	488	740	1,228	1,319	2,001	3,320	4,548	73.0
1971	629	2,756	3,385	1,194	5,231	6,425	9,810	65.5
1973	1,162	3,312	4,474	1,851	5,275	7,126	11,600	61.4
1975	620	1,587	2,207	2,046	5,238	7,284	9,491	76.7
1977	1,363	3,303	4,666	1,911	4,630	6,541	11,207	58.4
1979	723	2,140	2,863	3,567	10,558	14,125	16,988	83.1
1981	1,417	4,393	5,810	1,810	5,611	7,421	13,231	56.1
Mean	831	2,351	3,182	2,336	6,367	8,703	11,885	72.6

[a] Using Fraser River annual catch/escapement ratio (Append. 14).

calculated total adult production (catch plus escapement). The resulting marine survival for the 1957 to 1979 broods averaged 1.7% (range 0.5%-5.0%; Table 9). By comparison, the marine survival for similar broods of the Fraser River pink salmon averaged 3.2% (range 0.8-5.4%; Table 9). The relatively lower marine survival of the Jones Creek stock may be due to underestimation of the catch component (see previous section). However, the above comparison is weakened by the greater accuracy of fry and adult estimates for the Jones Creek system compared to those for the Fraser River.

CHUM SALMON

Chum escapement

During 1934 to 1953, before the operation of the hydroelectric project and prior to spawning channel construction, the annual chum escapement to Jones Creek averaged approximately 450 fish (Table 1). From 1954 to 1981, chum escapement to the channel and Jones Creek averaged 175 fish annually or around 40% of the pre-channel population size, with approximately 60% of the total chum returns spawning in the channel (Table 1).

Comparison of the chum escapement estimates for the Jones Creek system before and after channel construction is biased for the same reasons as were advanced earlier for pink salmon. In addition, chum counts into the creek after channel construction were not corrected for poor visibility since no adjustment factor exists for chum. Therefore, the available chum escapement estimates provide only an index of the relative abundance of chum spawners. Also, since the enumeration program was targeted at the odd-year pink salmon runs, only alternate years of chum runs were monitored regularly. Finally, the early portion of the chum run was generally missed since chum enter Jones Creek earlier than do pink salmon.

Chum adult migration timing and spawning distribution

Chum adults migrated past the fence into the Jones Creek spawning channel over a period of approximately one month, from around mid-September to mid-October (Table 10). The 50% completion date for migration past the fence averaged September 26. Chum spawning mortality in the channel occurred approximately 11 days after channel entry, as indicated by the difference between 50% migration timing and 50% dead recovery (Table 10).

Both day and night migrations were observed. Migration timing of chum into the channel was largely related to the dates of channel operation and closely paralleled that of pink salmon.

Water temperature during chum adult migration into the channel declined from around 12°C in mid-September to around 10°C by mid-October (Fig. 21, Table 17).

The Jones Creek chum are one of the earliest arriving stocks in the Fraser River (Palmer 1972). Chum generally enter Jones Creek in early September, about two weeks before pink salmon and when the channel is still dry. Therefore, the

Table 9. Marine survival of pink salmon from Jones Creek system (creek & channel) and from Fraser River, 1957 - 1979 broods.

Brood Year	JONES CREEK SYSTEM			FRASER RIVER
	Total estimated fry production[a] (X 1,000)	Total estimated adult return[b] (catch & escapement)	Marine survival (%)	Marine survival[c] (%)
1957	498.5	15,423	3.1	N/A[d]
1959	1,010.6	8,911	0.9	N/A
1961	1,146.2	9,561	0.8	3.7
1963	1,151.6	5,585	0.5	0.8
1965	1,380.9	26,269	1.9	4.7
1967	379.8	4,548	1.2	1.6
1969	196.4	9,810	5.0	5.0
1971	501.4	11,600	2.3	2.8
1973	728.9	9,491	1.3	1.7
1975	1,221.4	11,207	0.9	2.9
1977	1,120.7	16,988	1.5	3.0
1979	998.9	13,231	1.3	5.4
Mean	861.3	11,885	1.7	3.2

[a] From Tables 4 and 5.

[b] Table 8.

[c] From IPSFC Annual Reports.

[d] Not available.

Table 10. Chum adult migration timing and dead recovery in Jones Creek spawning channel, 1959 - 1979.[a]

Year	Period of migration through fence[b]	Duration of migration[b] (days)	50% Fence migration	50% Dead recovery	Period of channel residence[c] (days)
1959	Sept. 14 - Oct. 12[d]	28	Sept. 24	Oct. 3	10
1961	Sept. 13 - Oct. 12	30	Sept. 22	Oct. 5	14
1973	Sept. 20 - Oct. 22	32	Sept. 30	Oct. 9	10
1977	Sept. 19 - Oct. 16	28	Sept. 27	Oct. 8	12
1979	Sept. 21 - Oct. 19	29	Sept. 29	Oct. 6	8
Mean ± 1S.E. (days)	-	29.4±0.7	Sept. 26±1.5	Oct. 6±1.1	10.8±1.0

[a] Only those years were considered where a total of 50 or more chum spawners were counted through the fence.

[b] Interval between first and last chum counts through fence.

[c] Difference between 50% fence migration and 50% dead recovery in channel.

[d] Additional chum were observed to enter after fence was pulled.

earlier chum migrants are restricted to the lower creek reaches and only the later arriving chum spawn in the channel. In 1973, for example, water for the channel was turned on September 20, but chum spawners were observed in Jones Creek as early as the end of August.

Chum spawners had a less uniform distribution in the channel compared to pink salmon, with highest densities observed at the top and bottom ends of the channel (Fig. 18, Append 15). The downstream drift of spawned out fish may help explain the high densities in the lower channel sections.

Chum salmon are not discouraged from entering Jones Creek channel. Competition between pink and chum spawners for space within the spawning area does not appear to be a problem, unlike in the Big Qualicum River (Walker and Lister 1971). This is partly due to the smaller size of the chum population and their apparent preference for the upper end of the channel. It was also observed that chum generally deposit their eggs deeper than do the pink salmon (G. Wilson, pers. comm.).

Chum adult age, length and sex composition

Chum adults sampled for age in the spawning channel and Jones Creek showed no obvious or consistent difference in age composition between the two areas; consequently, annual data for the system were pooled each year. Age 3 chum were relatively scarce in all the years sampled; age 4 chum predominated in three of the four years sampled when they ranged from 78% to 95% of the total fish sampled; and age 5 chum predominated in 1979 with 62% of total fish (Table 11).

Compared to above, the mean age composition of the Fraser River chum sampled at Cottonwood Drift during 1970 to 1979 was 21% at age 3 (range 3% - 54%), 72% at age 4 (range 44% - 94%), and 7% at age 5 (range 0.5% - 24%) (Palmer 1972 and DFO, unpublished data). Therefore, the Jones Creek chum appear to return at an older age compared to the overall Fraser River chum stocks. The large proportion of 5-year old chum observed in the Jones Creek channel in 1979 was not related to the size of parental stock but was related to the relatively high 5-year old component (13%) observed among the Fraser River chum that year (M. Farwell, DFO, pers. comm.).

Mean postorbital-hypural length of chum adults sampled in the spawning channel and Jones Creek averaged 57.4 cm for males and 56.0 cm for females (Table 12). Although the females were consistently smaller than the males, annual length differences between the sexes were not always significant ($p < 0.05$). Also, no significant size difference ($p < 0.05$) was observed between chum sampled in the channel and in Jones Creek (Table 12). Compared to the Jones Creek stock, chum sampled in the Fraser River and its tributary spawning areas during 1970 to 1978 were slightly larger (59.9 cm for males and 57.8 cm for females) but the difference was not significant ($p < 0.05$; Palmer 1972 and DFO, unpublished data).

Sex composition of chum sampled in the spawning channel during 1955 to 1981 averaged 56.1% females (range 44.0%-66.7%; Table 13). This is similar to the 1970 to 1978 mean female composition of the total Fraser River chum escapement of 53.2% (range 47.6%-59.1%; DFO, unpublished data).

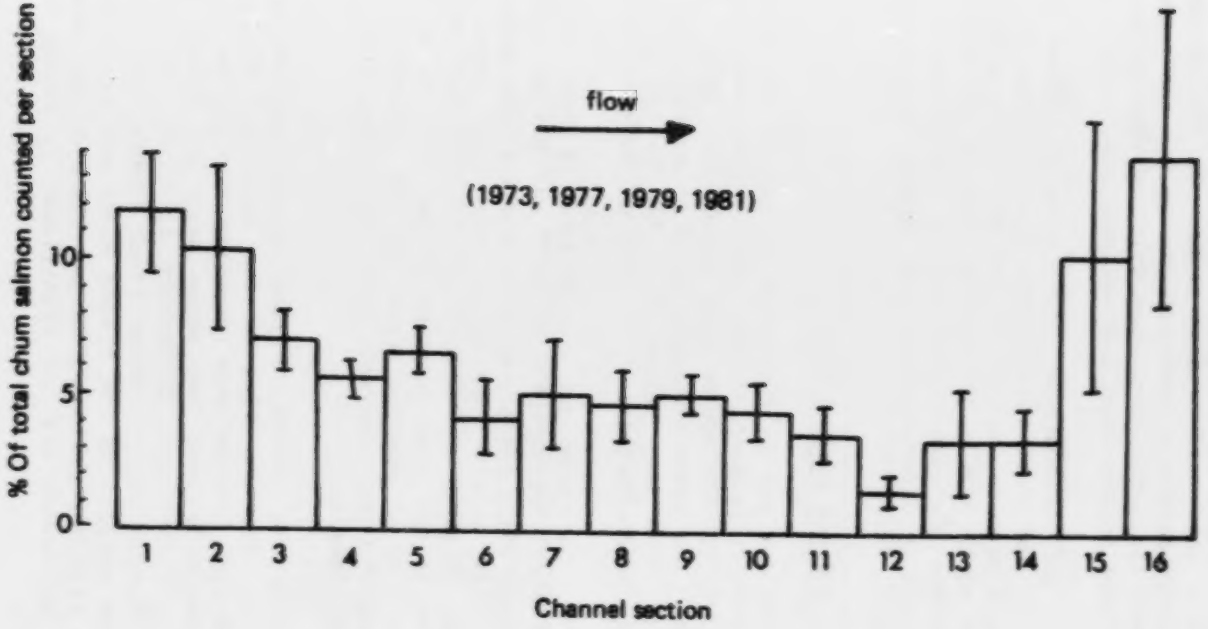


Fig. 18. Mean chum salmon spawning distribution in Jones Creek channel, 1973 – 1981 (see Fig. 2 for location of channel sections; vertical bars indicate ± 1 S.E.).

Table 11. Age composition of chum adults sampled in the spawning channel and Jones Creek, 1973 - 1981 (n gives sample size).[a]

Year	Sampling period	n	% Age		
			3	4	5
1973	Sept. 26 - Oct. 22	272	0.4	77.9	21.7
1977	Sept. 28 - Oct. 15	107	0	95.3	4.7
1979	Sept. 29 - Oct. 22	102	18.6	19.6	61.8
1981	Sept. 16 - Oct. 25	233	0	94.4	5.6

[a] 1975 return not sampled.

Table 12. Mean postorbital-hypural length (L± 1S.E.) of adult chum males and females in spawning channel and Jones Creek, 1973 - 1981 (n gives sample size).

Year	CHANNEL				CREEK				CHANNEL & CREEK			
	Male		Female		Male		Female		Male		Female	
	(n)	L	(n)	L	(n)	L	(n)	L	(n)	L	(n)	L
1973	(104)	58.0 ± 0.3	(104)	56.4 ± 0.2	(31)	60.2 ± 0.7	(51)	56.7 ± 0.4	(135)	58.5 ± 0.3	(155)	56.5 ± 0.2
1975		-[a]		-		-		-		-		-
1977	(44)	54.4 ± 0.5	(46)	54.1 ± 0.5	(11)	54.3 ± 1.1	(18)	53.3 ± 0.6	(55)	54.4 ± 0.4	(64)	53.9 ± 0.4
1979	(28)	58.2 ± 1.0	(27)	56.9 ± 0.5	(14)	58.9 ± 1.7	(29)	57.5 ± 0.7	(48)	58.6 ± 0.8	(61)	57.4 ± 0.4
1981[b]		-		-		-		-	(97)	57.9 ± 0.4	(107)	56.3 ± 0.2
Mean		56.9 ± 1.2		55.8 ± 0.9		57.8 ± 1.8		55.8 ± 1.3		57.4 ± 1.0		56.0 ± 0.7

[a] Not sampled.

[b] Channel and creek data pooled.

Table 13. Chum adult escapement, egg deposition and fry production in Jones Creek spawning channel, 1955 - 1981 brood years.

Brood year	No. spawners[a]	No. Females	% Females[b]	Fecundity[c] (eggs/female)	% Spawning success[c]	Actual egg deposition[d] (X 1000)	Measured fry migration (X 1000)	Egg-to-fry survival (%)
1955	160	93	58.1	3257	97.9	296.5	75.2	25.4
1956	300	200	66.7	3257	97.9	637.7	121.8	19.1
1957	27	13	48.1	3257	97.9	41.5	19.6	47.2
1959	71	41	57.8	3257	99.4	132.7	35.9	27.1
1961	65	35	53.8	3257	92.3	105.2	28.6	27.2
1963	138	78	56.5	3257	97.9	248.7	99.7	40.1
1965	37	22	59.5	3257	97.9	70.1	43.9	62.6
1967	33	22	66.7	3257	100.0	71.7	9.9	13.8
1969	100	44	44.0	3257	100.0	143.3	19.4	13.5
1971	5	3	60.0	3257	97.9	9.6	1.7	17.7
1973	248	133	53.6	3257	98.6	427.1	187.6	43.9
1975	24	14	57.1	3257	97.9	44.6	14.8	33.2
1977	179	96	53.4	3257	94.3	294.8	139.3	47.3
1979	63	30	48.2	3257	98.6	96.3	14.8	15.4
1981	157	92	58.4	3257	99.6	298.4	253.6[e]	85.0
Mean	107	61	56.1 ± 1.6 (± 1S.E.)	-	97.9	194.5	71.1	34.6±5.2 (±1S.E.)

[a] See Append. 5a for details.
[b] From dead recovery data (Append. 5a).
[c] See Append. 16 for details.
[d] Potential egg deposition corrected for spawning success.
[e] But only 251,400 live fry due to trapping mortality.

Chum fecundity, egg retention and deposition

Fecundity of chum females from Jones Creek was not available. Consequently, the mean fecundity of Fraser River chum of 3,257 eggs/female was utilized (Append. 16). Spawning success of chum females (actual/potential egg deposition) x 100 averaged 97.9% in the channel and 98.8% in the creek (Append. 16). The estimated actual egg deposition was calculated as for pink salmon and averaged 194,500 eggs per year (range 9,600-637,700) in the channel and 122,100 eggs per year (range 16,100-275,500) in the creek (Tables 13 & 14). During the 1955 to 1981 brood years, the spawning channel received approximately 61% of all chum eggs deposited in the creek and channel.

Chum fry production and migration timing

The annual production of chum fry in the spawning channel averaged 71,100 (range 1,700 to 253,600; Table 13). The estimated annual fry production in the creek below the channel averaged 11,000 (range 1,400 to 39,100; Table 14).

Chum fry usually migrated from the channel during April and May, with the run 50% completed on April 26 (range April 8 to May 20; Fig. 19, Table 15). Duration of the downstream run averaged 55 days (range 43 to 78 days; Table 15). The above timing estimates were biased by the fry enumeration period. As was observed for pink fry, chum fry migrated largely after dusk.

Water temperature during chum fry migration from the channel increased from around 5°C in April to around 6°C after mid-May (Fig. 21, Table 17). Although most chum fry migrated out of the channel one to two weeks earlier than pink fry (Figs. 14 and 19), the changes in migration timing between years were comparable for the two species, indicating that similar factors such as water temperature affected fry movement. In particular, the early migration timing of chum fry in 1958 and 1970 was also observed for pink fry and was probably related to the relatively high spring water temperatures observed in those years (Append. 19 b & d).

Compared to the Fraser River chum fry sampled at Mission from 1965 to 1978 (DFO, unpublished data), the 50% migration timing of the Jones Creek channel fry occurred approximately nine days later (April 26 vs April 18).

The production of chum fry in the channel was underestimated in most years by up to 5% for the same reasons as were advanced for pink fry. In addition, some chum fry remained to rear in the channel after the end of enumeration period and were uncounted. Chum fry production in the creek below the channel was probably underestimated by over 10%, mostly due to the incomplete adult counts which governed the egg production estimates.

Chum fry size

Lengths and weights of chum fry migrating from the Jones Creek channel averaged 39.0 mm and 349 mg respectively (Table 16). The mean length was similar to the mean value of 38.7 mm reported for the 1967 to 1972 broods of Big Qualicum River channel fry (Fraser et al., in prep'n), and 40.0 mm reported for the 1977 brood Fraser River wild chum fry sampled at Mission (Levy et al. 1979).

Table 14. Chum adult escapement, egg deposition and fry production in Jones Creek, 1955 - 1981 brood years.

Brood year	No. spawners[a]	% Females[b]	No. Females	Fecundity[c] (eggs/female)	% Spawning[d] success	Actual egg deposition[e] (X 1000)	Estimated fry migration[f] (X 1000)	Egg-to-fry survival[f] (%)
1955	-[g]	58.1	-	3257	98.8	-	-	-
1956	30	66.7	20	3257	98.8	64.4	5.8	9
1957	26	48.1	13	3257	98.8	41.8	3.8	9
1959	19	57.8	11	3257	98.8	35.4	3.2	9
1961	26	53.8	14	3257	100.0	45.6	4.1	9
1963	19	56.5	11	3257	98.8	35.4	3.2	9
1965	30	59.5	18	3257	98.8	57.9	5.2	9
1967	33	66.7	22	3257	100.0	71.7	6.5	9
1969	111	44.0	49	3257	98.8	157.7	14.2	9
1971	8	60.0	5	3257	98.8	16.1	1.4	9
1973	159	53.6	85	3257	99.5	275.5	24.8	9
1975	100	57.1	57	3257	98.8	183.4	16.5	9
1977	106	53.4	57	3257	99.8	185.3	16.7	9
1979	71	48.2	34	3257	94.0	104.1	9.4	9
1981	230	58.4	134	3257	99.6	434.7	39.1	9
Mean	-	56.1 ± 1.6 (± 1S.E.)	-	-	98.8	122.1	11.0	9

[a] See Append. 5b for details.
[b] Using corresponding channel sex composition.
[c] As for channel.
[d] See Append. 16 for details.
[e] Potential egg deposition corrected for spawning success.
[f] Derived by applying mean natural egg-to-fry survival of B.C. chum salmon (9%; from SEP design criteria, 1981 draft).
[g] No data.

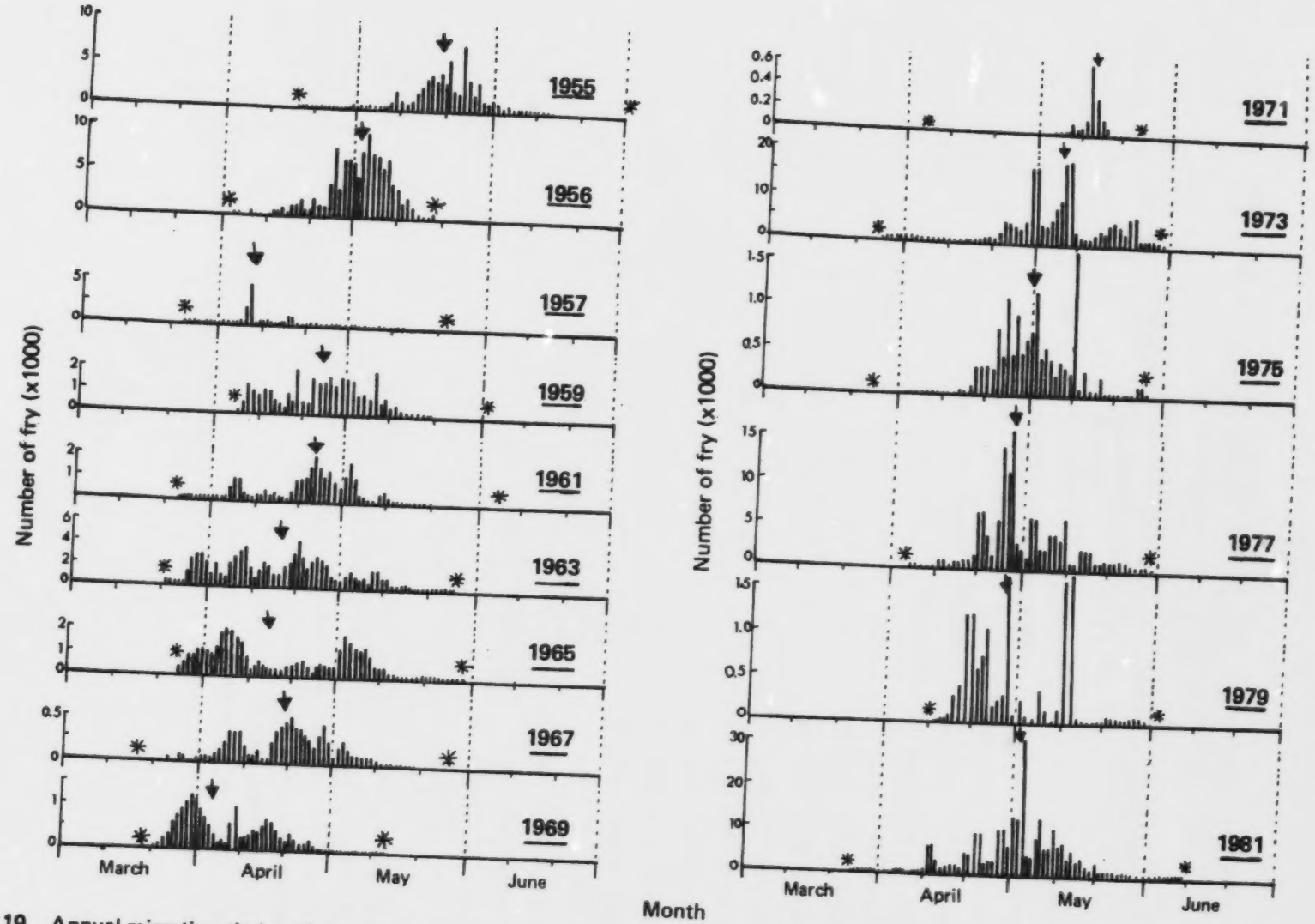


Fig. 19. Annual migration timing of chum fry from Jones Creek spawning channel, 1955 – 1981 brood years (asterisks indicate start and end of enumeration; arrows indicate 50% completion of counts).

Table 15. Chum fry enumeration and migration timing into Jones Creek spawning channel, 1955 - 1981 broods.

Brood year	Enumeration period	No. fry (X 1000)	Migration timing		
			Duration period[a]	Duration (days)[a]	50% of Total count
1955	April 17 - June 12	75.2	April 17 - June 12	57	May 20
1956	April 2 - May 18	121.8	April 2 - May 18	47	May 2
1957	March 19 - May 23	19.6	March 24 - May 6	44	April 8
1959	April 6 - June 2	35.9[b]	April 6 - May 24[b]	49[b]	April 25
1961	March 24 - June 5	28.6	March 30 - May 25	57	April 24
1963	March 22 - May 27	99.7[b]	March 22 - May 27[b]	67[b]	April 17
1965	March 26 - May 29	43.9[b]	March 26 - May 21[b]	57[b]	April 15
1967	March 17 - May 27	9.9	March 24 - May 16	54	April 20
1969	March 19 - May 13	19.4	March 21 - May 8	49	April 4
1971	April 5 - May 23	1.7[b]	May 4 - May 15[b]	11[b]	May 13
1973	March 26 - May 29	187.6[b]	March 27 - May 29[b]	64[b]	May 6
1975	March 26 - May 27	14.8	April 15 - May 27	43	May 1
1977	April 4 - May 30	139.3[b]	April 5 - May 30[b]	56[b]	April 28
1979	April 12 - June 4	14.8	April 12 - May 29	48	April 27
1981	March 24 - June 10	253.6[c]	March 25 - June 10	78	May 2
Mean (± 1S.E.)	-	71.1	April 3 - May 24	55±3[d]	April 26±3

[a] Where first and last day's count each exceeds 20 fry.

[b] Size of run slightly underestimated and duration of run probably underestimated by a few days since some 200 to 600 fry migrated each day on first and/or last day of count.

[c] Only 251,300 live fry due to trapping mortality of 2,252 fry.

[d] Excludes 1971 brood since migration period underestimated due to small size of run.

Table 16. Mean length (L) and weight (W) of chum fry in Jones Creek spawning channel for 1975-1981 odd-year broods, and overall mean length of chum fry in Big Qualicum River channel for 1967-1972 broods and in Fraser River at Mission for 1977 brood.

Brood year	Sampling Period	Mean length (+ 1S.E.) No. fish	No. samples	L(mm)	Mean weight (+ 1S.E.) No. fish	No. samples	W (mg)
		JONES CREEK CHANNEL					
1975	April 29 - May 7	61	3	38.7±0.1	61	3	340±5
1977	April 21 - May 11	270	9	38.9±0.2	270	9	353±2
1979	April 21 & 25	33	2	38.4±0.2	33	2	353±3
1981	April 14 - May 13	200	8	40.1±0.2	800	16	428±9[a]
Mean[b] ± 1S.E.	-	-	-	39.0±0.4	-	-	349±4[c]
		BIG QUALICUM RIVER CHANNEL					
1967-1972 Mean[b] ±1S.E.	-	-	-	38.7±0.2	-	-	-
		FRASER RIVER AT MISSION					
1977 Mean ±1S.E.	-	-	-	40.0±0.4	-	-	-

[a] Heavier due to sampling technique since water was not sufficiently drained from fry prior to weighing in aggregate (see methods).

[b] Mean of annual means.

[c] Excludes 1981 brood weight.

Chum fry from the Jones Creek channel were sampled extensively from April 27 to May 23 in 1982. During that period, mean fry size increased from 39.6 mm to 42.5 mm and from 390 mg to 530 mg, indicating that rearing occurred.

Chum egg-to-fry survival

The annual egg-to-fry survival of chum salmon in the Jones Creek channel, based on the actual egg deposition and fry production estimates, averaged 34.6% (range 13.5% - 85.0%; Fig. 20, Table 13). These survival rates are biased somewhat since the egg deposition data were based on the Fraser River chum fecundity data, and the annual fry production was probably underestimated by up to 5%.

The above mean chum survival rate indicates that, as for pink salmon, the channel is more successful than a natural river. For example, the egg-to-fry survival of Fraser River chum fry averaged only 17.2% for the 1964-1980 broods (Fig. 20, Append. 17). However, the mean survival rate in the Jones Creek channel was significantly ($p < 0.05$) lower than the survival rate reported for the Big Qualicum River spawning channel No. 2 which averaged 66.3% for the 1967 to 1979 broods (Fig. 20, Append. 17). As was indicated for pink salmon, the frequent and heavy sedimentation in the Jones Creek channel after egg deposition, combined with occasional ice scouring, were probably the major factors responsible for the relatively low survival of chum fry in the Jones Creek channel.

It is of interest to note that the year-to-year differences in survival rates of pink and chum fry in the Jones Creek channel did not always show a similar trend. For example, egg-to-fry survival of the 1975 brood was 64% for pink but only 33% for chum (Figs. 15 and 20). Compared to pink eggs, chum eggs probably suffered greater mortality that year due to severe sedimentation since chum eggs were deposited mainly in the upper channel sections where sedimentation was the heaviest (G. Wilson, pers. comm.). Other factors such as spawning density may be also involved.

The total adult return and marine survival of chum adults originating from the Jones Creek system were not determined due to incomplete escapement, catch and age composition data.

COHO SALMON

Coho adults

During 1934 to 1953, the annual coho escapement to Jones Creek averaged 210 fish (Table 1). From 1954 to 1981, coho escapement to the system averaged 60 fish annually, or around 30% of the pre-channel population size. The fish barrier across the creek at the channel exit probably prevents coho from utilizing important traditional spawning and rearing areas above the barrier.

Coho spawned both in the channel during its operation, and in the creek below, but the degree of channel utilization is unknown. Coho migrate

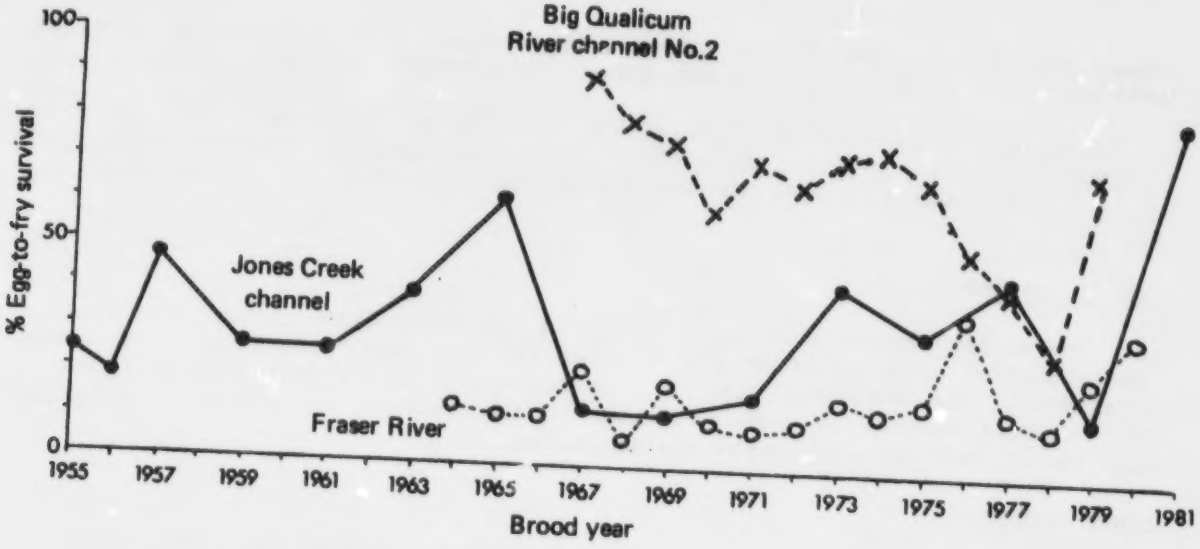


Fig. 20. Chum egg-to-fry survival rates by brood year in Jones Creek spawning channel, Big Qualicum River spawning channel and Fraser River for 1955 – 1981 brood years where available (see Append. 17 for sources of data).

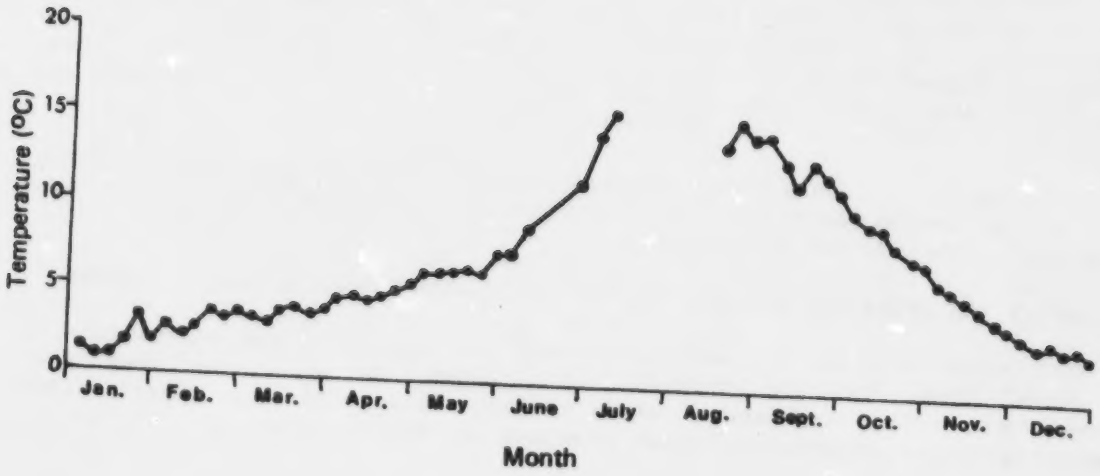


Fig. 21. Five-day mean surface water temperatures in Jones Creek spawning channel averaged over 1954 – 1982.

relatively late in the season compared to chum and pink salmon, and continue entering Jones Creek well after the end of adult enumeration program.

Biological sampling of coho adults was limited to length and age data collected in October 1973. Ten adults (males and females) averaged 41.8 ± 2.1 cm (± 1 S.E.), and 21 adults sampled for scales were 14.3% age 3_2 and 85.7% age 4_2.

Coho juveniles

The annual migration of coho fry out of the Jones Creek channel was greatly underestimated since it often peaked after the pink fry enumeration program was terminated. The available data on coho fry migrants are presented in Appendix 18. Limited rearing of coho juveniles in the channel occurred in some years when the channel was not completely dewatered.

OTHER SPECIES

In addition to the migration out of the channel of pink, chum and coho fry, occasional observations were made of chub, lampreys, sculpins, rainbow trout, cutthroat trout and coho and steelhead smolts. Rainbow trout captured in 1978 measured 13 cm to 23 cm (n = 21); cutthroat trout measured 18 cm (n = 1).

PHYSICAL SAMPLING

Five-day mean surface water temperatures in the Jones Creek (1949, 1952 - 1953) and in the spawning channel (1954 - 1982) are shown for each year in Appendix 19 and are summarized in Figure 21 and Table 17. Mean surface water temperature in the spawning channel during 1954 to 1982 increased gradually from about 2°C in January to over 15°C by July, then declined steadily to around 3°C by December. On several occasions during January and February, water temperature dropped below 0°C resulting in ice formation (Append. 19). Water temperatures monitored at the top and bottom ends of the channel in 1978 and 1979 generally differed by less than 0.1°C.

Discharge in the Jones Creek spawning channel generally averaged 0.7 m^3/sec to 0.8 m^3/sec during adult migration and spawning, and 0.3 m^3/sec to 0.4 m^3/sec during egg incubation and fry migration.

PROBLEMS IN THE OPERATION AND MAINTENANCE OF THE JONES CREEK SPAWNING CHANNEL

Four major problems are associated with the operation and maintenance of the Jones Creek spawning channel. In order of importance they are: sedimentation, icing, maintenance of an adequate flow regime and deterioration of existing timber structures. These problems are discussed below.

Sedimentation

The most serious operational problem encountered since channel construction in 1954 has been the large accumulation of sand and silt in the channel gravel. This is caused by the instability in the tributary watershed resulting from

Table 17. Five-day mean surface water temperatures (T°C) in Jones Creek spawning channel averaged over 1954 - 1982 (n gives years of data).

Date	n	T(°C)	Range (°C)	Date	n	T(°C)	Range (°C)
Jan. 5	3	1.2	0.0 - 2.1	July 5	1	14.4	-
10	4	1.0	0.0 - 1.7	10	1	15.7	-
15	3	1.1	0.7 - 1.8	15	-	-	-
20	3	1.9	0.0 - 3.2	20	-	-	-
25	3	3.4	2.9 - 4.0	25	-	-	-
31	4	1.9	-0.6 - 3.0	31	-	-	-
Feb. 5	4	2.7	2.4 - 3.0	Aug. 5	-	-	-
10	4	2.2	0.0 - 3.8	10	-	-	-
15	3	2.9	1.8 - 4.0	15	-	-	-
20	5	3.2	2.4 - 4.2	20	2	14.0	13.0 - 15.0
25	4	3.4	2.4 - 4.4	25	2	15.5	14.8 - 16.1
28	3	3.6	3.1 - 4.4	31	2	14.5	13.9 - 15.0
Mar. 5	3	3.1	1.6 - 5.1	Sept. 5	2	14.6	14.1 - 15.0
10	4	3.3	1.6 - 4.4	10	4	13.2	11.7 - 14.7
15	3	3.8	2.9 - 4.4	15	7	11.9	10.9 - 13.2
20	4	4.0	3.4 - 5.1	20	14	13.3	10.7 - 19.2
25	6	3.6	1.6 - 5.1	25	15	12.3	11.0 - 15.8
31	9	4.0	2.2 - 5.9	30	15	11.6	8.6 - 14.7
Apr. 5	9	4.5	3.2 - 6.7	Oct. 5	15	10.4	7.3 - 14.8
10	11	4.8	3.1 - 6.8	10	14	9.6	6.8 - 13.9
15	11	4.6	3.1 - 7.6	15	13	9.6	7.9 - 12.0
20	11	4.8	3.0 - 6.9	20	14	8.6	6.0 - 11.7
25	12	5.3	3.9 - 6.7	25	11	7.9	5.2 - 9.5
30	12	5.5	3.5 - 7.5	31	9	7.6	3.0 - 12.5
May 5	11	6.2	4.2 - 9.3	Nov. 5	5	6.7	4.7 - 8.4
10	10	6.3	5.0 - 8.4	10	4	6.2	2.0 - 8.0
15	9	6.4	4.7 - 8.4	15	3	5.8	3.7 - 7.3
20	9	7.0	5.3 - 9.4	20	3	5.1	2.0 - 7.6
25	7	6.3	4.3 - 7.9	25	3	4.5	1.7 - 7.1
31	6	7.5	6.0 - 8.5	30	3	4.1	2.9 - 5.3
June 5	2	7.5	7.0 - 8.0	Dec. 5	3	3.7	3.2 - 4.2
10	1	9.0	-	10	3	3.1	2.7 - 3.4
15	-	-	-	15	3	3.4	1.7 - 4.7
20	-	-	-	20	3	2.9	1.7 - 3.6
25	-	-	-	25	3	3.2	1.7 - 4.2
30	1	11.6	-	31	4	2.5	1.0 - 4.1

steep terrain, erodible soils, impermeable subsoil, heavy precipitation, a drainage system that carries most of the surface runoff directly into the main channel of Jones Creek, and a lack of road surfacing gravel (Wilford 1975). Erosion of the channel banks also contributes to sedimentation. Finally, leaves and organic debris from the vegetation around the channel become a problem during fall and winter, when they block the channel intake.

The problem of sedimentation in the channel has been severely aggravated by logging during the late 1960's to 1979 and road building within the watershed. The impact of these activities was especially felt in late October 1971, when road construction in the area coincided with a period of heavy rainfall. Erosion and the diversion of a small creek resulted in the deposition of a large amount of sediment throughout Jones Creek and the adjacent spawning channel. The silt completely blanketed the channel bottom, nullifying the gravel cleaning operation which occurred earlier that year (S. Zablosky, pers. comm.).

In 1972, the Whonnock Lumber Company was charged under the Fisheries Act with depositing a deleterious substance into water flowing through salmon spawning grounds, and was fined $3,000. In addition, corrective measures were proposed by DFO that could improve water quality and prevent further silting. The company agreed not to resume work in the watershed until June 1 because road construction before and during the hatching of pink salmon eggs (April-May) coincided with the spring thaw and would only result in additional silting. At the request of DFO, the Whonnock Lumber Company also installed more culverts, cleaned ditches and reduced the slope of their road banks.

During the stormy fall and winter of 1973, extreme erosion of road banks and surfaces of the logging operation again led to sediment problems in the newly cleaned channel. By November, the two desilting basins were completely filled with bedload material and the surplus sediment was spilling into the channel. A study conducted during 1973 to 1974 showed that siltation in the channel caused considerable egg mortality in the uppermost channel sections and resulted in a substantial loss in fry production (Append. 12).

In 1975, gravel in the channel was replaced but fall floods produced massive mud slides into the creek, once again silting the channel. The timely efforts of the B.C. Hydro and Power Authority in cleaning the channel's settling basins in January 1976, together with mild winter conditions, were the major reasons for the fairly high survival of channel pink fry that year (64%).

Although the Whonnock Lumber Company was implementing many of the modifications to their logging operations requested by the DFO, these measures were not totally effective. Furthermore, the company's plan to recommence logging within the area in the mid-1980's means that sedimentation problems may worsen in the near future. The B.C. Forest Service also contributes to the problem due to their delay in quick reseeding of logged areas within the watershed. This in turn prevents rehabilitation and stabilization of the effected slopes (D. Toews, DFO memo, June 1976).

However, even in the absence of logging, sedimentation of the channel will continue due to unstable soils and large land slides in the watershed. More important, the two desilting basins are inadequate for long-term operation. Only the coarser sands settle out and the two catch basins quickly become filled during heavy freshets and usually become totally ineffective long before fry migration from the channel.

Icing

During severe winters, problems are encountered when frazil or anchor ice forms in the channel, especially at the invert controls. This can result in scouring of the gravel during the spring break up, and damming and diversion of flow which leads to bank erosion. This in turn leads to increased egg and alevin mortality. Severe icing in the channel was observed in the winters of 1956/57 (20 cm - 30 cm of ice covered the channel), 1964/65 and 1969/70. To minimize damage, ice jams are now broken up as soon as they are observed.

Flow regime

In some years, the flows required during the spawning period (0.7 m^3/sec - 0.8 m^3/sec) are not available from dam spillage or residual flow below that site. During these periods, additional discharge is provided by pumping water from the Jones Lake reservoir or siphoning it from nearby Boulder Creek.

A reduced flow of 0.4 m^3/sec is sufficient during incubation. However, on occasion (as in December 1975, January 1976 and December 1979), the flow was temporarily interrupted when gravel and debris brought down by flood conditions completely plugged the gate valve and prevented water from entering the channel. To remedy this problem, a 15 cm x 15 cm wire mesh was installed at the channel intake in 1981 to keep out the debris.

Deterioration of existing timber structures

Due to the natural deterioration of the channel timber structures, considerable reconstruction is periodically required. For example, the barrier dam at the channel exit, built nearly 30 years ago, was partly rebuilt in 1981 and will require further reconstruction.

RECOMMENDATIONS

It is becoming increasingly uneconomic to continue reconditioning the Jones Creek spawning channel even on a biennial basis. To remedy this situation, the following recommendations are made concerning changes in the operation of the channel and possible enhancement measures.

Physical operation

1. Constructing a larger and more efficient settling basin and sluiceway (elevated intake) combination in order to limit the amount of suspended solids entering the channel. The sluiceway would flush out the bedload

materials accumulated in the settling basins, thereby bypassing the channel. It should be noted that flushing of Jones Creek channel with large amounts of water does not remove or control silting because increase in flow depth does not change the hydraulic gradient through the gravel.

2. Modifying the channel water intake structure in order to control flows in the channel during flood periods and to prevent flow blockage through the build up of debris in the pipe.

3. Developing more cost-efficient gravel cleaning procedures. At present, the B.C. Hydro and Power Authority is investigating the feasibility of utilizing a modified version of the type of gravel-cleaning machine that was developed by the IPSFC.

4. Stabilizing the channel banks using small rip-rap.

5. Center-notching the channel drop structures to facilitate the ascent of mature salmon and discourage poaching.

6. Continuing the maintenance of the timber fish diversion barrier.

Enhancement

The enhancement measures include:

1. Operating the channel every year for both spawning and rearing in order to increase the productivity of chum, coho and steelhead (the latter two species require a year or more of freshwater residence before migrating to the ocean).

2. Constructing a fishway at the fish diversion weir to allow coho, chum and steelhead to reach former spawning and rearing areas above the barrier.

3. Increasing channel size to accommodate more spawners.

The more intensive fish culture measures for the Jones Creek system proposed by G. Nielson, B. Shepherd, and D. Harding (DFO, 1981 memo) include:

4. For pink salmon - gravel incubators for eggs with direct release of fry below the channel. This measure would be applied only to the Jones Creek pink salmon since other Fraser River pink stocks in need of enhancement are geographically distant from Jones Creek (for the same reason, no chinook stocks will be enhanced at Jones Creek).

5. For chum salmon - gravel incubators for eggs, followed by fry rearing until 1 g either in rearing troughs or in lower end of channel. This measure would be applied to the Jones Creek and to adjacent upriver Fraser chum stocks.

6. For coho salmon - Heath tray incubators for eggs obtained from brood stock, followed by fry rearing until 2 g to 25 g in troughs or in modified channel sections; reared juveniles are to be returned to native streams for imprinting and release. This measure would be applied to the Jones Creek and to adjacent upriver Fraser coho stocks.

The success of the above intensive enhancement measures (No. 4, 5 and 6) will depend primarily on the availability of good water quality since the incubation supply must be silt-free. Suitable water may be obtained from Wahleach powerhouse supply, or wells may be installed. In the latter case, temperature of the groundwater would be one of the key factors in evaluating the suitability of this approach. Negotiations with the B.C. Hydro and Power Authority will be required regarding funding of the reconstruction and operation of the enhancement facilities for maintenance of the Jones Creek pink, chum and coho stocks. Other initiatives will be the responsibility of DFO.

ASSESSMENT OF THE JONES CREEK SPAWNING CHANNEL OPERATION AND PRODUCTION

The Jones Creek spawning channel succeeded only partially in its original objective to mitigate the effects of hydrodam construction on the Jones Creek salmon stocks. The annual pink salmon escapement to the channel increased from 400 in 1955 to a mean of approximately 2,000 adults. This is less than half of the original Jones Creek pink salmon run of approximately 4,250 fish. Additional annual escapement of about 800 pink salmon to the creek below the channel still leaves the total escapement well below the pre-channel levels. Also, the chum and coho runs to Jones Creek are less than half of their pre-channel levels.

The major reason for the low channel production is poor egg-to-fry survival due to extreme sedimentation of the channel. General overharvesting of stocks may also have contributed partly to the low adult returns.

On the other hand, the channel with its mean spawning population of 2,153 pink salmon (Table 1) appears to be functioning near its apparent optimum spawning capacity of 2,180 adults calculated to produce maximum egg-to-fry survival and fry yield. Therefore, increased adult returns to the channel probably could not be accommodated since the original channel design for 6,000 pink spawners greatly underestimated the spawner density requirements.

In general, the problems associated with the Jones Creek project arise from inexperience with a new technique at the time the channel was built; insufficient study of area topography and weather conditions; and most important, extreme instability of the watershed soils aggravated by logging operations. Although the channel banks and bed have stabilized and logging operations have temporarily ceased, siltation in the channel will remain a problem.

In conclusion, although the Jones Creek channel is relatively small and currently out of date in its design, and although extensive renovations would be difficult to justify, it nevertheless makes a valuable contribution to the maintenance of the Jones Creek pink salmon run and small runs of chum and coho. In addition, in the nearly 30 years of operation, the Jones Creek channel has

made significant contributions to spawning channel technology, pink salmon biology and the complexities of salmon transplants. With appropriate modifications designed to increase the egg-to-fry survival or the use of alternate enhancement techniques, the Jones Creek facility could increase in value as a production unit for the lower Fraser River salmon stocks.

SUMMARY

1. The Jones Creek spawning channel was constructed in 1954 by the B.C. Electric Company in order to mitigate the effects of hydro-dam construction on the Jones Creek salmon stocks, especially the odd-year pink salmon runs.

2. The channel operates every second year on a guaranteed flow of 0.8 m^3/sec during spawning and 0.4 m^3/sec during incubation. It currently has a spawning area of approximately 2,400 m^2 and an optimal spawning capacity of 2,180 pink salmon (based on 0.5 m^2/female).

3. Pink salmon

   The initial transplant of even-year pink salmon eggs in 1954 died out after two or three cycles.

   Annual pink salmon escapements to the channel since construction averaged 2,153 adults, and spawners migrated into the channel from around mid-September to mid-October; they died approximately 14 days after entry. Spawner density was relatively uniform throughout the channel length.

   Length of adults averaged 44.1 cm for males and 42.7 cm for females.

   Females comprised on the average 55.3% of pink spawners in the channel.

   Fecundity averaged 1,829 eggs per female.

   Spawning success averaged 95.8% in the channel and 95.0% in the creek.

   Actual egg deposition in the channel averaged 2.04 million per year (range 0.44 - 3.97 million); in the creek it averaged 0.81 million (range 0.39 - 1.51 million).

   Fry production in the channel averaged 747,800 per odd-cycle year (range 145,700 - 1,574,900); in the creek it averaged 105,300 (range 50,700 - 196,300).

   Median fry migration date for the channel averaged May 3; duration of downstream run averaged 59 days.

   Fry length and weight averaged 35.1 mm and 226 mg respectively.

   Egg-to-fry survival in the channel averaged 37.7% (range 8.5% - 79.1%).

Calculated catch plus escapement of pink salmon to the channel and Jones Creek averaged 11,885 fish during 1959 to 1981, with 73% originating in the channel.

Marine survival averaged 1.7% (range 0.5% - 5.0%).

4. Chum salmon

Annual chum escapements to the channel since construction averaged 107 adults, and spawners migrated into the channel from around mid-September to mid-October; they died approximately 11 days after entry. Highest spawner densities were observed at the top and bottom ends of the channel.

Chum generally returned at age 3, 4, and 5; age 4 was usually the dominant group (78% - 95% of the escapement).

Length of adults averaged 57.4 cm for males and 56.0 cm for females.

Females comprised on the average 56.1% of chum spawners in the channel.

Fecundity was based on Fraser River chum fecundity of 3,257 eggs per female.

Spawning success averaged 97.9% in the channel and 98.8% in the creek.

Actual egg deposition in the channel averaged 194,500 per year (range 9,600 - 637,700); in the creek it averaged 122,100 (range 16,100 - 275,500).

Fry production in the channel averaged 71,100 per year (range 1,700 - 253,600); in the creek it averaged 11,000 (range 1,400 - 39,100).

Median fry migration date for the channel averaged April 26; duration of downstream run averaged 55 days.

Fry length and weight averaged 39.0 mm and 349 mg respectively.

Egg-to-fry survival in the channel averaged 34.6% (range 13.5% - 85.0%).

5. Coho salmon

Coho escapements to the channel and Jones Creek since channel construction averaged 60 adults.

6. Mean water temperature in the channel increased from around 2°C in January to over 15°C in July, then declined to around 3°C by December.

7. Sedimentation aggravated by logging in the watershed during the 1970's and 1980's was the major problem in channel operation and maintenance and was responsible for much of the channel maintenance cost and incubation mortality. Other problems include ice scouring, inadequate flows and disintegration of timber structures in the channel.

8. Major recommendations include a new design of settling basin incorporating a sluiceway to reduce sedimentation in the channel; the use of mechanical gravel cleaners to reduce the cost of gravel cleaning and frequency of gravel removal; and stabilization of channel banks using rip-rap. More intensive enhancement measures include the use of Heath tray or gravel incubators and subsequent rearing of juveniles depending on the species.

9. The Jones Creek spawning channel succeeded only partially in its original objective since the channel supports on the average less than half of the original pink, chum and coho runs. Poor egg-to-fry survival due to extreme sedimentation combined with occassional ice scouring in the channel, and original underestimation of pink spawner density requirements are the major reasons for the relatively poor channel performance. Nevertheless, the channel is valuable in its maintenance of salmon runs. Its design should be improved as recommended or other salmonid enhancement measures should be introduced.

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Appendix 1. Jones Creek spawning channel dimensions, 1954 - 1983.

Year	FEET				METERS		
	Width[a]	Length	Area (ft^2)	Area (yd^2)	Width	Length	Area (m^2)
1954	~ 10	1920	19,200	2,133	~ 3	585.2	1,755.6
1955	15.0[b]	1920	28,800	3,200	4.6[b]	585.2	2,691.9
1956	15.0	1820[c]	27,300	3,033	4.6	554.7[c]	2,551.6
1957	15.0	1720[d]	25,800	2,867	4.6	524.3[d]	2,411.8
1959	15.0	1720	25,800	2,867	4.6	524.3	2,411.8
1961	15.0	1720	25,800	2,867	4.6	524.3	2,411.8
1963	15.0	1720	25,800	2,867	4.6	524.3	2,411.8
1965	15.0	1720	25,800	2,867	4.6	524.3	2,411.8
1967	15.5	1720	26,660	2,962	4.7	524.3	2,464.2
1969	15.5	1720	26,660	2,962	4.7	524.3	2,464.2
1971	15.5	1720	26,660	2,962	4.7	524.3	2,464.2
1973	15.5	1600[e]	24,800	2,756	4.7	487.7[e]	2,292.2
1975	15.5	1600	24,800	2,756	4.7	487.7	2,292.2
1977	15.8	1600	25,280	2,809	4.8	487.7	2,341.0
1979	15.8	1600	25,280	2,809	4.8	487.7	2,341.0
1981	15.8	1600	25,280	2,809	4.8	487.7	2,341.0
1983[f]	16.0	1600	25,600	2,844	4.9	487.7	2,389.7

[a] Gradual changes in channel width with time, after initial severe bank erosion, were assigned arbitrarily to years due to lack of data.

[b] Severe bank erosion resulted in rapid channel widening.

[c] Settling basin No. 2 installed (length of 30.5 m (100 ft)); effective channel length reduced by same amount.

[d] Counting apron moved 30.5 m (100 ft) above channel outlet; effective channel length reduced by same amount.

[e] Settling basin No. 2 lengthened by 30.5 m (100 ft) and counting apron moved upstream additional 6.1 m (20 ft); effective channel length reduced by same amount.

[f] Channel measured April 25, 1983 by G. Nielsen and D. Harding (DFO).

Appendix 2. Summary of Jones Creek channel maintenance work and costs, 1954 - 1981.

Brood year	No. pink spawners in channel	Pink egg-to-fry survival (%)	Maintenance work[a]	Estimated cost ($)	Comments
1954	Egg plant	42	Channel construction.	$3,800	Bank erosion.
1955	400	36	-	-	Bank erosion, fall floods.
1956	2,800 + spawners	9	-	-	Second settling basin installed (30 m long).
1957	1,056	32	Gravel cleaned and sacrified repairs.	5,000	Severe icing ('56/'57); two major washouts.
1958	30	-	Gravel cleaned.	400	
1959	2,119	50	Gravel removed, cleaned and replaced.	3,780	
1960	-	-	-	-	
1961	4,388	27	?	No record.	
1962	-	-	-	-	
1963	2,806	35	?	No record.	
1964	-	-	-	-	
1965	2,167	53	Gravel cleaned.	3,888	Severe icing ('64/'65).
1966	-	-	-	-	
1967	2,674	11	Gravel cleaned in upper sections; settling basins cleaned	3,900	Icing; bank scour.
1968	-	-	-	-	
1969	1,319	13	Gravel flushed and sacrified.	3,700	
1970	-	-	-	-	Severe icing (early Jan.).
1971	1,194	36	Gravel removed, cleaned and replaced; settling basins cleaned.	14,300	Extreme siltation (late October).
1972	-	-	-	-	
1973	1,481	35	All gravel replaced; settling basins cleaned and enlarged; new inserts, weirs and fence; sealed dyke.	21,388	Extreme siltation in fall; settling basin No. 2 extended from 30 m to 60 m.
1974	-	-	-	-	
1975	2,048	64	Gravel replaced; settling basins cleaned and enlarged.	23,334	Extensive siltation (Oct.).
1976	-	-	Settling basins cleaned (January).	4,080	
1977	1,911	51	Gravel replaced in upper channel sections; settling basins cleaned.	4,000	
1978	-	-	-	-	
1979	3,567	33	Gravel replaced in upper channel sections; remaining gravel in channel screened and flushed; settling basins cleaned; barrier dam at channel entrance repaired.	30,000	
1980	-	-	-	-	
1981	1,810	79	Gravel replaced; settling basins cleaned; counting installation replaced with concrete structure; barrier dam repaired.	70,000	

[a] Generally includes additional miscellaneous work such as repair of fish barrier and maintenance of insect controls.

Appendix 3. Construction cost analysis and gravel cleaning frequency in spawning channels in B.C.[a]

Channel	Principal species	Year built	Channel width (m)	Channel area (m^2)	Construction cost ($)	Cost/area ($/$m^2$)	Gravel cleaning frequency	Comments
Jones Creek	Kok	1954	3.0	1,756	60,800	34.62	2 years	Construction by B.C. Hydro; 2 settling basins.
Robertson Creek	Kok, chinook	1960	10.7	8,361	240,000	28.70	-	Not used for spawning; cost includes intake works, drop structures and basic channel; excludes overhead costs.
Seton Creek No.1	Kok	1961	6.1	5,518	35,000	6.30	2 years[b]	Constructed by IPSFC; no settling basin; siphon supply from B.C. Hydro canal.
Big Qualicum No.1	Chum	1963	5.5	3,344	75,000	22.60	-	Used for rearing only; no settling basin; excludes overhead costs.
Weaver Creek	Sockeye	1965	6.1	16,722	275,000	16.40	4 years	Constructed by IPSFC; includes $20,000 land cost; intake with 453 m pipeline and settling basin.
Fulton River No.1	Sockeye	1965	9.1	11,388	586,000	51.50	1 year	Intake in river; no settling basin; excludes overhead costs.
Rutledge	Chinook	1965	7.6	1,839	~ 300,000	163.10	~ 3 years	Constructed by B.C. Hydro; water supplied via floor diffuser from electric pumps which draw from the river; no settling basin.
Gates Creek	Sockeye	1967	6.1	11,287	306,000	27.10	4 years[b]	Built by IPSFC; intake in river with settling basin, including deep lake intake supply line.
Seton Creek No.2	Kok	1967	6.1	17,558	218,000	12.40	2 years	Constructed by IPSFC; no settling basin; siphon supply from B.C. Hydro canal.
Big Qualicum No.2	Chum	1967	12.2	12,542	190,600	15.20	1 year	Intake in river; divider wall type settling basin (not removing fines); excludes overhead costs.
Kirkut	Sockeye	1968	12.2	33,009	1,532,000	46.40	1 year	Intake in river; same basin as in Big Qualicum No.2.

[a] Unpublished data (G. Mialson, Feb. 1972).

[b] Gravel cleaned to remove dead eggs and algal build-up.

Appendix 4. Summary of pink and chum adult enumeration methods in spawning channel and Jones Creek, 1949 - 1981. (X indicates that method was used).

	CHANNEL (above fence)				CREEK (below fence)	
	Fence count	Live count/section		Dead recovery	Live count	Dead recovery
1949	No channel; live and dead counts, and tag recovery.					
1950	No channel; live counts.					
1951	No channel; live and dead counts.					
1953	Channel construction.				-	-
1954	No adults; egg plant.				-	-
1955	No fence.	X		X	-	-
1956	-[a]	X		X	-	-
1957	X	-		X	X	X
1959	X	-		X	X[b]	-
1961	X	-		X	X	X
1963	-	X[b]		X	X[b]	X
1965	-	X	Pink only.	X	X	X
1967	X	X	Pink only.	X	X	X
1969	X Pink only.	X	Pink only.	X	X	X
1971	-	X	Pink only.	X	X	X
1973	X	X		X	X	X
1975	X	-		X	X	-[c]
1977	X	X		X	X	X
1979	X	X		X	X	X
1981	-	X		X	X	X

[a] Not done.

[b] Limited data.

[c] Very high water.

Appendix 5a. Total fence count, dead recovery and escapement estimates for pink and chum salmon in Jones Creek spawning channel, 1954 - 1981.

Year	Enumeration period[a]	Total fence count		Total dead recovery		Escapement estimate	
		PINK	CHUM	PINK	CHUM	PINK	CHUM
1954	NO ADULTS - EGG PLANT						
1955	Sept. 13 - Nov. 2	NO FENCE		289	93	400[b]	160[b]
1956	Aug. 17 - Oct. 19	N/D[e]	N/D	2,406	250	2,800[b,c]	300[b]
1957	Sept. 10 - Oct. 22	1,056	18	801	27	1,056[d]	27[f]
1958	-	N/D	N/D	---		39[b,c]	-
1959	Sept. 11 - Oct. 27	2,119	60	1,573	71	2,119[d]	71[f]
1961	Sept. 11 - Oct. 25	4,388	65	3,846	52	4,388[d]	65[d]
1963	Sept. 12 - Oct. 25	N/D	N/D	2,806	138	2,806[f]	138[f]
1965	Sept. 15 - Oct. 28	N/D	N/D	2,005	37	2,147[b]	37[f]
1967	Sept. 13 - Oct. 30	2,874	N/D	2,647	33	2,874[d]	33[f]
1969	Sept. 16 - Nov. 2	1,308	N/D	1,318	100	1,319[g]	100[f]
1971	Sept. 29 - Nov. 11	N/D	N/D	832	5	1,194[b]	5[f]
1973	Sept. 20 - Oct. 24	1,851	248	1,700	235	1,851[d]	248[d]
1975	Sept. 21 - Oct. 21	2,046	24	1,702	21	2,046[d]	24[d]
1977	Sept. 19 - Oct. 19	1,911	145	1,807	148	1,911[d]	179[g]
1979	Sept. 18 - Oct. 22	3,453	49	3,504	57	3,567[g]	63[g]
1981	Sept. 16 - Oct. 28	N/D	N/D	1,810	157	1,810[f]	157[f]

[a] Includes live and dead recovery periods.
[b] Maximum live and cumulative dead (no fence count).
[c] From egg transplant.
[d] Total fence count.
[e] Not done (fence installed but not fence counts made).
[f] Total dead recovery.
[g] Live count and cumulative dead on last day of fence operation.

Appendix 5b. Total dead recovery and escapement estimates for pink and chum salmon below fence, Jones Creek, 1954 - 1981.

Year	Enumeration period[a]	Total dead recovery		Escapement estimate		Comments
		PINK	CHUM	PINK	CHUM	
1954	-	N/D[A]	N/D	0	100	
1955	-	N/D	N/D	N/D	N/D	
1956	-	N/D	N/D	N/D	30	
1957	Sept. 10 - Oct. 22	361	21	962[b]	26[c]	
1958	-	N/D	N/D	- 0	N/D	
1959	Sept. 23 - Oct. 16	N/D	N/D	455[d]	19[e]	Very limited data.
1961	Sept. 6 - Oct. 25	378	25	769[b]	26[c]	
1963	Sept. 25 - Nov. 23	512	19	700[f]	19[g]	Very limited visual counts
1965	Sept. 7 - Oct. 30	763	30	782[c]	30[c]	Poor visibility.
1967	Sept. 13 - Nov. 2	484	24	869[b]	33[c]	Poor visibility.
1969	Sept. 16 - Nov. 2	419	81	488[b]	111[c]	Poor visibility.
1971	Sept. 23 - Nov. 2	418	8	629[c]	8[c]	Poor visibility.
1973	Sept. 4 - Oct. 22	271	130	1,162[b]	159[c]	Poor visibility.
1975	-	N/D	N/D	620[e]	100[e]	High water.
1977	Sept. 7 - Oct. 19	328	75	1,363[b]	106[c]	
1979	Sept. 18 - Oct. 25	586	55	723[h]	71[c]	Heavy discharge.
1981	Sept. 16 - Oct. 26	1,182	212	1,417[c]	230[c]	

[a] Not done.
[b] (Peak live and cumulative dead) x 2.6 - (No. pink that entered channel after that date).
[c] Maximum daily live and cumulative dead.
[d] Data incomplete; escapement = max. live count x 2.6 = 175 x 2.6 = 455.
[e] Max. live count.
[f] Data incomplete; escapement = total dead recovery + 200 estimated missed in dead recovery.
[g] Total dead recovery.
[h] (Peak live and cumulative dead) x 2.6; many carcasses washed out due to heavy discharge so that did not subtract later channel entries.

Appendix 6. Even-year experimental transplants in Jones Creek spawning channel, 1954, 1956.

	1954	1956
No. spawners	0	2,800
No. eggs deposited	0	2,780,000
No. eggs stripped and fertilized at Lakelse	2,976,000	-
No. eyed eggs shipped from Lakelse	2,738,000	-
No. live eggs planted in channel	2,606,000	1,000,000
No. eggs hatched in channel	2,140,000	Not available
No. fry migrating from channel	1,100,000	321,000
Egg-to-fry survival	42.2%[a] (37.0%)[b]	8.5%[a]

[a] From live eggs planted.
[b] From original stripped eggs.

Appendix 7. Calculation of pink adult live residence period in Jones Creek spawning channel.[a]

Year	Peak migration past fence	Peak dead recovery	Live residence period in channel (days)
1957	Sept. 27	Oct. 13	17
1959	Sept. 25	Oct. 6	12
1961	Sept. 23	Oct. 10	18
1967	Sept. 29	Oct. 12	14
1969	Sept. 23	Oct. 10	18
1973	Oct. 5	Oct. 15	11
1975	Oct. 3	Oct. 13	11
1979	Sept. 27	Oct. 7	11
Mean (± 1S.E.)	Sept. 28 ± 1.6	Oct. 11 ± 1.1	14.0 ± 1.1

[a] Only those years with an obvious migration peak are considered.

Appendix 8. Pink spawning distribution in Jones Creek channel, 1965 - 1981.

Year	Inspection period[a]	Total pinks counted	% OF TOTAL PINKS COUNTED PER CHANNEL SECTION																		
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Total
1965	Sept. 20 - Oct. 17	23,439	7.7	8.3	8.1	6.7	8.4	6.3	7.4	7.7	5.4	5.2	6.7	6.3	3.7	3.0	4.4	3.8	3.3	1.6	100
1967	Sept. 21 - Oct. 18	22,521	9.6	3.8	2.8	6.1	2.6	2.8	3.1	6.7	5.9	7.0	7.0	7.6	5.1	6.1	7.9	7.1	8.7	6.2	100
1969	Sept. 16 - Oct. 31	12,000	3.9	3.4	5.7	6.6	6.5	4.7	5.6	6.2	7.8	5.0	6.5	6.9	4.5	4.7	7.6	6.5	6.2	6.0	100
1971	Sept. 20 - Oct. 30	7,307	6.1	6.3	6.2	7.6	6.7	6.2	6.2	6.3	5.8	5.9	5.8	3.7	3.4	2.8	4.3	3.4	2.5	3.2	100
Mean (± 95% C.I.)			7.1 ± 1.3	6.0 ± 1.4	6.2 ± 1.3	6.5 ± .7	6.1 ± 1.2	5.0 ± .9	5.6 ± .9	6.5 ± .7	5.5 ± .6	5.5 ± .6	6.0 ± .5	5.4 ± .7	4.2 ± .6	4.2 ± .5	5.0 ± 1.0	4.7 ± .6	5.2 ± 1.4	4.3 ± 1.1	100
1975[b]	Sept. 22 - Oct. 16	3,885	11.0	8.5	9.3	7.1	9.9	7.7	7.6	6.7	6.5	4.9	6.1	3.7[c]	2.8[c]	3.7[c]	5.1	6.6	-	-	100
1977	Sept. 21 - Oct. 17	18,558	8.0	7.7	7.7	7.3	5.6	6.8	4.7	4.4	5.8	6.1	4.9	4.4	3.7	3.9	6.4	13.1	-	-	100
1979	Sept. 20 - Oct. 22	7,550	10.9	6.5	6.4	6.9	6.2	5.9	6.4	5.6	5.6	5.7	6.3	5.2	4.8	4.0	5.7	7.1	-	-	100
1981	Sept. 20 - Oct. 23	14,776	8.8	7.9	6.5	5.9	4.7	5.6	6.1	4.9	4.7	5.2	6.2	4.8	4.9	5.4	9.7	8.5	-	-	100
Mean ± 95% C.I.			8.7 ± 1.8	7.7 ± 1.4	7.6 ± 1.7	6.8 ± 1.3	6.6 ± 1.9	6.4 ± 1.1	6.4 ± 1.4	5.8 ± 1.3	5.3 ± 1.0	5.3 ± 1.0	5.5 ± 1.3	4.3 ± 1.3	4.1 ± 1.5	4.3 ± 1.4	6.8 ± 3.1	6.0 ± 1.5			100

[a] Not continuous.

[b] In 1975, section 7 was converted to a settling basin and fish counting fence was moved upstream, resulting in only 16 channel sections.

[c] A plastic liner in these three sections was probably responsible for low utilization by fish.

Appendix 9. Fecundity, egg retention and spawning success of pink females in spawning channel and Jones Creek, 1955 - 1981 (n gives sample size).

Year	Channel							Creek			
	Fecundity			Egg retention[a]		Unspawned females	Spawning success[b]	Egg retention[a]		Unspawned females	Spawning success[b,c]
	n	Mean (±1S.E.)	Range	(n)	Mean	(n) No.	(%)	(n)	Mean	(n) No.	(%)
1955		1,829[d]									
1956		1,829[d]		——[e]		——	95.8[d]				
1957		1,829[d]		——		——	95.8[d]	——		——	95.0[d]
1959		1,829[d]		——		——	95.8[d]	——		——	95.0[d]
1961		1,829[d]			50[d]	(806) 5	96.7	——		——	95.0[d]
1963		1,829[d]			50[d]	(2023) 66	94.1	——		——	95.0[d]
1965		1,829[d]		——		——	95.8[d]		57[d]	(211) 4	95.0
1967		1,829[d]		——		——	95.8[d]	——		——	95.0[d]
1969		1,829[d]			50[d]	(1345) 52	93.5	——		——	95.0[d]
1971		1,829[d]		(10)	23	(614) 4	98.1		57[d]	(302) 8	94.3
1973	(20)	1,680 (±38)	1,329-1,924	——		——	95.8[d]	——		——	95.0[d]
1975		1,829[d]		(300)	12	(302) 4	98.0	——		——	95.0[d]
1977	(8)	1,981 (±55)	1,728-2,216	(230)	78[f]	0[f]	95.7	(63) 14		(65) 1.5	96.9
1979	(15)	1,834 (±81)	1,273-2,515	(88)	78	(951) 9	95.1	——		——	95.0[d]
1981		1,829[d]		(172)	93	(175) 3	93.3	(12) 20		(157) 4	96.5
				(88)	18	(89) 1	97.9	(100) 138		0	92.5
Mean[g]		1,829			50	——	95.8	——	57	——	95.0[d]

[a] Excludes unspawned females.
[b] (Actual egg deposition X 100) ÷ (Potential egg deposition).
[c] Using corresponding channel fecundity.
[d] Mean of other years.
[e] No data.
[f] Egg retention includes dead, unspawned and partially spawned females.
[g] Includes only years with actual data.

Appendix 10. Comparison of egg-to-fry survival rates for odd-year pink salmon from Jones Creek and Seton Creek spawning channels and from Fraser River.[a]

Brood Year	Egg-to-fry survival (%)			
	Jones Creek channel	Upper Seton channel	Lower Seton channel	Fraser River
1955	36.0[b]	-[c]	-	-
1956	8.5	-	-	-
1957	32.3	-	-	-
1959	49.9	-	-	-
1961	26.6	52.4	-	9.2
1963	35.2	21.7	-	11.7
1965	52.8	34.5	-	18.4
1967	11.2	44.4	40.2	11.1
1969	13.2	46.5	61.8	9.7
1971	35.7	85.5	57.1	12.7
1973	35.3	74.8	62.9	15.7
1975	64.0	82.1	66.6	18.7
1977	50.5	47.4	57.5	16.0
1979	32.6	45.7	55.6	9.0
1981	79.1	-	-	-
Mean ± 1S.E.	37.7 ± 4.9	53.5 ± 6.6	57.4 ± 3.2	13.2 ± 1.2

[a] Data for Upper Seton and Lower Seton channels from Cooper (1972) and from IPSFC Annual Reports; data for Fraser River from IPSFC Annual Report (1981)

[b] See Table 4 for details.

[c] No data.

Appendix 11. Gravel and oxygen sampling in Jones Creek spawning channel, 1968.

Methods

In May 1968, after completion of fry migration, 16 selected gravel samples and corresponding subgravel oxygen samples were taken in the channel to evaluate the terminal incubation conditions (Append. Fig. 11-1). Several redd sites were also examined for indication of egg-to-fry survival.

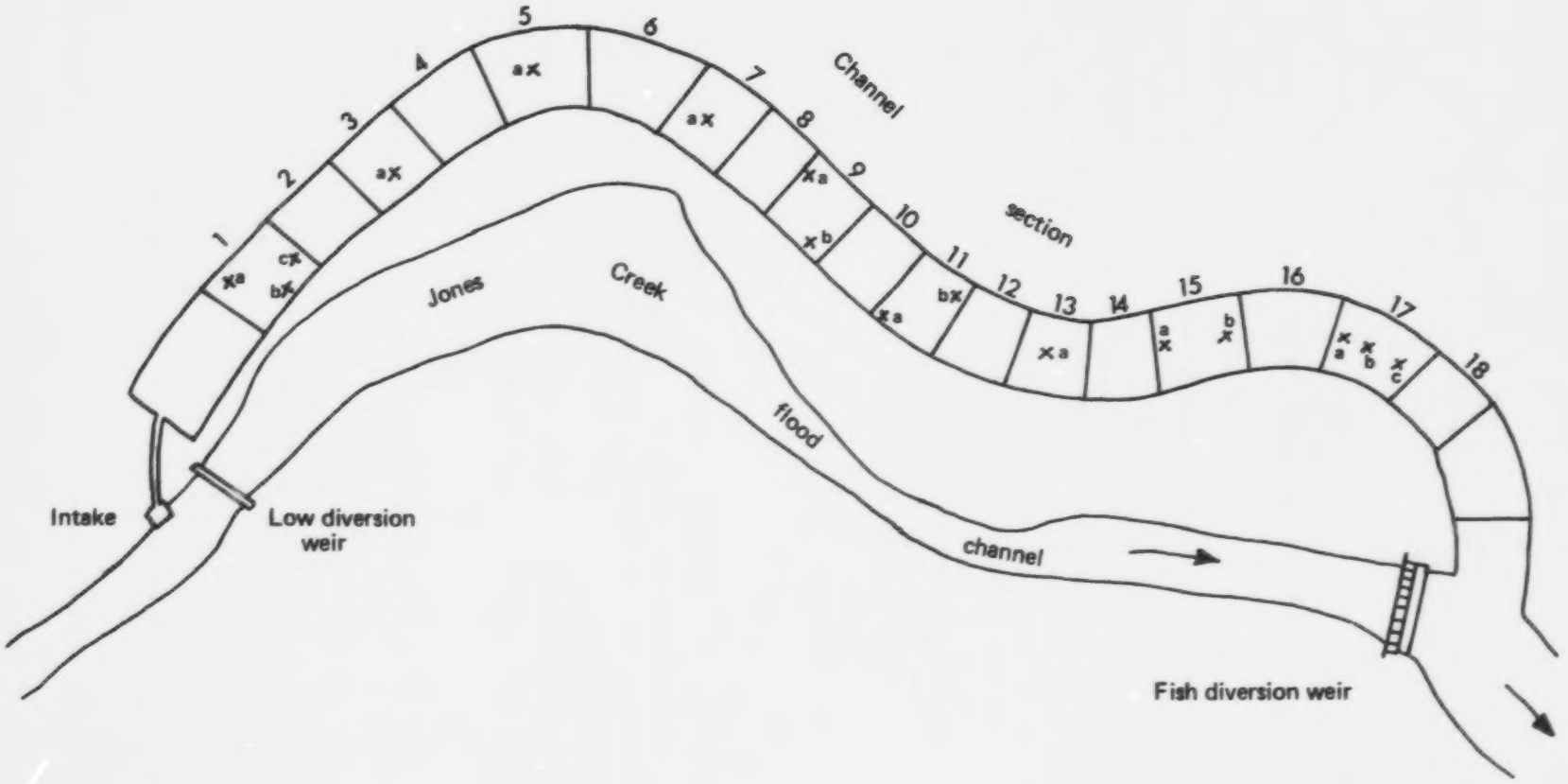
Results

Analysis of the gravel samples showed that half of the samples contained more than 20% by volume of fines less that 1.3 cm in diameter and nearly 40% of the samples contained more than 8% by volume of fines less than 0.5 cm in diameter (Append. Table 11-1). By comparison, at the start of channel operation in 1954, gravel size ranged from 6 mm to 38 mm in diameter. Fine material in the channel was most abundant in sections 9 and 11 (Append. Table 11-1). This was probably due to the proximity of sampling sites to channel banks where erosion and silting were apparently high (Append. Fig. 11-1).

At the sites sampled, subgravel dissolved oxygen values ranged from 2.2 ppm to 8.0 ppm, with the lowest values recorded in section 9 (Append. Table 11-1). The examined redd sites revealed a high incidence of dead advanced alevins.

Appendix Table 11-1. Analysis of gravel samples and subgravel oxygen samples in Jones Creek spawning channel, May 1968.

	1			3	5	7	9		11		13	15		17		
% of sample by volume with particle size diameter (cm)	a	b	c	a	a	a	a	b	a	b	a	a	b	a	b	c
Greater than 3.8	4.5	4.2	6.4	20.3	5.8	3.8	0	2.4	0	0	3.1	73.0	5.7	1.0	3.9	0
1.3 - 3.8	88.5	77.9	80.5	68.7	56.0	41.9	23.0	20.7	24.5	25.4	71.0	26.4	92.0	88.0	88.1	91.7
0.5 - 1.3	7.2	8.2	9.6	8.8	27.7	45.9	58.0	58.3	56.2	58.1	21.7	0	1.3	12.4	3.5	5.3
0.25- 0.5	0	0.1	0	0	3.2	3.6	8.0	5.1	5.5	5.1	0	0	0	0.9	0	0.1
0.2 - 0.25	0	0	0	0	0.7	0.2	0.8	0.1	0.5	0.2	0	0	0	0.1	0	0
0.1 - 0.2	0	0.5	0	0	0.9	0.5	1.1	0.8	4.3	0.6	0	0	0	0.3	0	0
Less than 0.1	3.3	9.9	3.1	0	4.7	4.0	10.1	8.4	8.7	5.2	3.8	3.2	0	3.1	4.1	3.7
% Organic detritus	0.2	0	0.2	0	0	0	0	0	0	0.1	0.1	0.1	0	0	0	0
Subgravel dissolved oxygen (ppm)	5.0	7.0	5.0	8.0	6.0	3.8	4.0	2.2	6.0	7.0	5.0	6.0	7.0	7.0	7.0	6.0



Append. Fig. 11–1. Location of gravel and corresponding dissolved oxygen sampling sites (a–c) in Jones Creek spawning channel, May 1968 (diagrammatic).

Appendix 12. Evaluation of effects of siltation in Jones Creek spawning channel, 1973-1974.

Introduction and Methods

During the adult pink salmon enumeration program at the Jones Creek spawning channel in 1973 (Sept. 19 - Oct. 21), heavy silt loads were carried into the channel. The sedimentation resulting from rainy weather and high water in Jones Creek was of sufficient level to reduce to zero the visibility in the channel water despite the reduction of channel flow to a minimum operating level of 0.4 to 0.6 m^3/sec. By the end of the adult enumeration program, settling basins No. 1 and No. 2 were almost completely filled and a considerable amount of silt was deposited in the upper channel area. This incident essentially nullified the maintenance work carried out just prior to the 1973 pink adult migration when all channel gravel was replaced with washed and graded gravel, and the two settling basins were cleaned and enlarged.

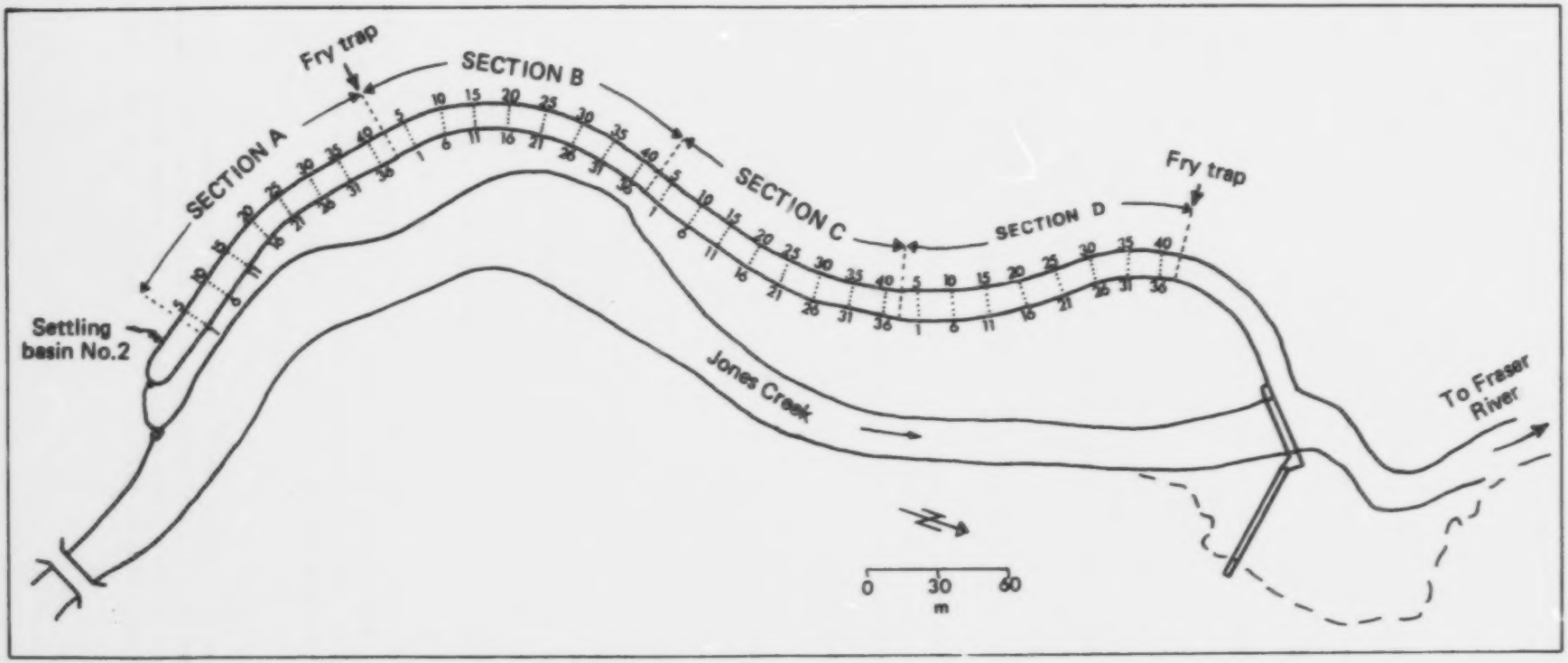
To quantify the accummulation of fine materials in the channel, a gravel sampling program was undertaken from September 27, 1973 to April 17, 1974, utilizing an "insitu" frozen core gravel sampler. The total channel length between the lower end of settling basin No. 2 and the adult counting apron (~ 490 m) was divided into four segments (A, B, C & D), each approximately 122 m long (Append. Fig. 12-1). Each segment was marked with eight cross-sections, one at every 15 m, and each cross-section had five sampling stations, giving a total of 40 sampling sites in each channel segment (A to D) (Append. Fig. 12-1). Five samples were taken at random from each main segment during each sampling period. To insure randomness, a table of random numbers was used to locate sampling sites; however, no station was sampled more than once.

To quantify the egg and alevin mortalities in the Jones Creek channel, hydraulic sampling was carried out from February 5 to March 15, 1974. An imaginary grid was laid out in the channel with each 30 m section containing 50 grid areas, each approximately 2.8 m^2. Sampling was conducted randomly alternating between every second 30 m section (i.e. 0-30 m, 60-90 m; and the following series in the 30-60 m, 90-120 m etc.). In this way, 10 hydraulic samples were obtained in each main channel segment (A-D) in each sampling period.

To quantify the egg-to-fry survival in the channel, two Wolfe traps were installed in 1974, one at the end of section A and one at the end of section D (Append. Fig. 12-1). The two trapping facilities enumerated all the surviving pink fry originating upstream of each of the two traps.

Results

The first gravel samples were obtained on September 27, 1973, when the spawning gravel was still relatively clean. Only three small samples from the top channel section A were obtainable due to technique difficulties resulting from high water temperatures (12°C - 13°C) and the lack of a matrix of fine



Append. Fig. 12–1. Location of gravel sampling sites (1973 – 1974) and of fry traps (1974) in Jones Creek spawning channel.

materials that aid the "adhesive" properties of the freezing technique. The very fine material observed in the September samples (Append. Table 12-1) originated mainly from the channel bank which was disturbed by machinery during gravel replacement prior to the adult pink salmon migration. No further sampling was possible at this time.

Additional gravel sampling was conducted successfully in November, December, January and April, and a total of 80 samples with 20 from each main segment (A to D) were analyzed to show the accummulation of silt by section (Append. Fig. 12-2, Append. Table 12-1). In section A, the accummulation of fine material (1.2 mm and smaller) reached a level of 18% by January. Sections B and D had generally lower levels of silt accummulation.

The hydraulic sampling (Append. Table 12-2) showed that heavy egg and alevin mortalities occurred in section A during the alevin stage, just prior to the emergence of fry in March and April 1974 (egg and alevin survival in section A dropped from 48.4% in February to 11.2% in March; no such decline was observed in the lower channel sections). As expected from above, relatively low pink egg-to-fry survival, based on pink egg and fry production estimates, was observed in section A (16.3%) compared to the lower channel sections (46.1%) (Append. Table 12-3). Similarly, chum egg-to-fry survival was only 15.7% in section A compared to 67.9% in the lower channel sections (Append. Table 12-3). However, migration timing of pink fry in section A and sections B to D was similar indicating that heavy siltation of gravel had no apparent effect on fry migration timing. Pink fry size was also similar in the two areas:

PINK FRY SIZE (n indicates sample size)

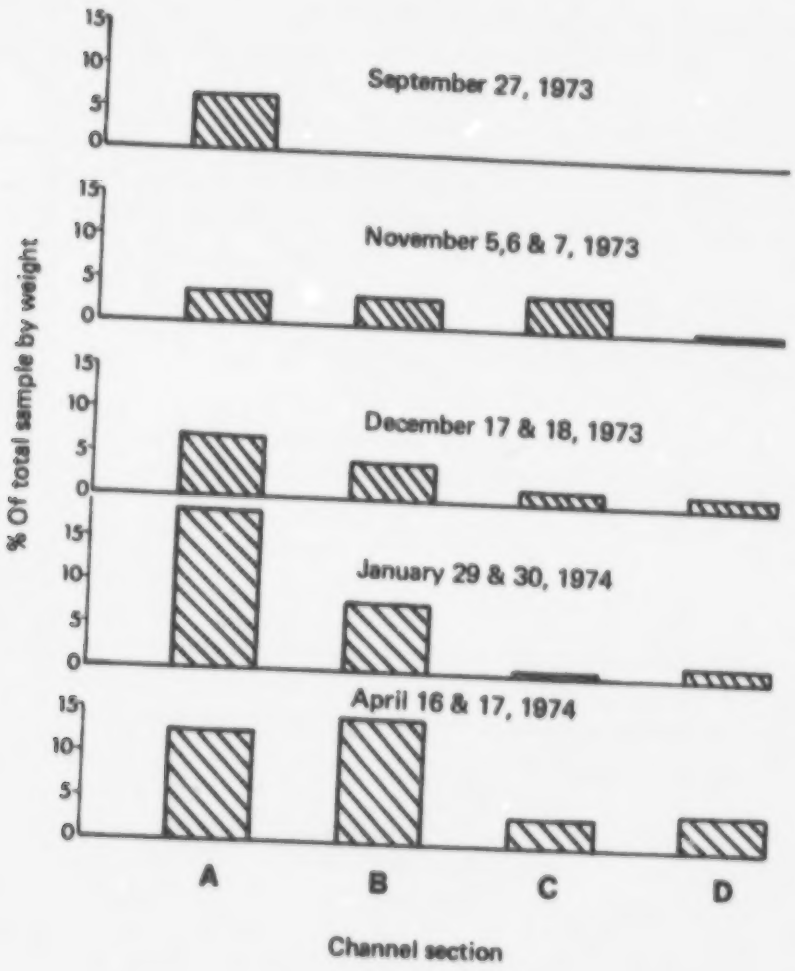
	Length ± 1 S.E.		Weight ± 1 S.E.	
	n	(mm)	n	(mg)
section A	120	35.4 ± 0.3	120	228.4 ± 3.0
sections B,C,D	141	35.4 ± 0.1	141	221.9 ± 2.1

In conclusion, the data obtained indicate that siltation of a magnitude high enough to cause significant mortalities in salmon eggs and alevins has occurred in the Jones Creek spawning channel during 1973/74. In addition, increased siltation was directly related to reduced egg and aleven survival and consequently reduced fry production from the channel, with greatest losses observed in the uppermost channel sections.

Appendix Table 12-1. Analysis of gravel samples in Jones Creek spawning channel, Sept. 1973 - April 1974.

Sampling date	% Of sample with particle size diameter (mm)	CHANNEL SECTION A	B	C	D
Sept. 27/73	Greater than 9.5	89.1	-[a]	-	-
	2.4 - 9.5	2.9	-	-	-
	1.2 - 2.4	1.5	-	-	-
	0.3 - 1.2	3.2	-	-	-
	0.07 - 0.3	2.2	-	-	-
	Less than 0.07	1.2	-	-	-
	Total sample wt.(g)	11,202.7	-	-	-
Nov. 5,6&7/73	Greater than 9.5	86.4	94.9	94.4	99.7
	2.4 - 9.5	9.4	1.0	1.2	0.1
	1.2 - 2.4	0.3	0.3	0.4	0
	0.3 - 1.2	0.8	0.7	1.1	0
	0.07 - 0.3	1.9	1.9	1.5	0.1
	Less than 0.07	1.2	1.2	1.4	0.1
	Total sample wt.(g)	77,501.9	75,498.6	69,163.0	88,150.2
Dec. 17&18/73	Greater than 9.5	92.2	94.5	97.9	98.0
	2.4 - 9.5	0.6	1.0	0.2	0.4
	1.2 - 2.4	0.2	0.4	0.1	0.1
	0.3 - 1.2	0.7	0.8	0.2	0.4
	0.07 - 0.3	4.9	1.7	0.5	0.3
	Less than 0.07	1.4	1.6	1.1	0.8
	Total sample wt.(g)	56,977.6	68,297.6	60,843.0	
Jan. 29&30/74	Greater than 9.5	74.3	89.3	99.6	97.7
	2.4 - 9.5	3.6	1.1	0.1	0.6
	1.2 - 2.4	3.8	1.7	0	0.2
	0.3 - 1.2	13.2	4.4	0	0.7
	0.07 - 0.3	3.4	2.5	0.1	0.3
	Less than 0.07	1.7	1.0	0.2	0.5
	Total sample wt.(g)	67,497.6	52,217.9	52,902.4	61,620.3
April 16&17/74	Greater than 9.5	80.2	84.3	95.9	94.1
	2.4 - 9.5	3.9	0.5	0.3	1.1
	1.2 - 2.4	3.2	1.0	0.1	0.4
	0.3 - 1.2	7.0	5.0	0.2	1.3
	0.07 - 0.3	3.6	7.4	1.3	1.8
	Less than 0.07	2.1	1.8	2.2	1.3
	Total sample wt.(g)	53,702.8	60,095.8	78,151.8	64,418.0

[a] Not sampled.



Append. Fig. 12–2. Percent fine material smaller than 1.2 mm by weight of total gravel sample in Jones Creek spawning channel, 1973 – 1974.

Appendix Table 12-2. Survival of eggs and alevins in Jones Creek spawning channel (sections A, B, C & D) as indicated by hydraulic sampling, February - March 1974.

Date	SECTION A			SECTIONS B, C & D		
	Total eggs & alevins	No. live eggs & alevins	Survival rate	Total eggs & alevins	No. live eggs & alevins	Survival rate
Feb. 5, 6, 11 & 12	2,593	1,128	48.4%[a]	830	392	47.2%
Feb. 26 & 27	614	232	37.8%	1,198	533	44.5%
March 14 & 15	887	99	11.2%	685	401	58.5%

[a] Mean of Feb. 5 & 6 data (31.9%) and Feb. 11 data (64.8%).

Appendix Table 12-3. Egg-to-fry survival of pink and chum salmon in Jones Creek channel as indicated by egg and fry production estimates, 1973 brood.

	PINK		CHUM	
	Section A	Sections B, C, D	Section A	Sections B, C, D
No. eggs[a]	603,861	1,073,530	196,474	230,643
No. fry migrating	98,543	495,190	30,929	156,714
Egg-to-fry survival	16.3%	46.1%	15.7%	67.9%

[a] Assumed that area A (channel sections 1-4) had 36% of pink spawners (Append. 8) and 46% of chum spawners (Append. 15).

Appendix 13. Pink egg-to-fry survival and total pink fry production in Jones Creek channel related to pink (and pink plus chum) female spawner density, 1955 - 1981 broods.

Brood Year	Pink egg-to-fry survival[a] (%)	Total fry produced (millions)[b]		No. female spawners[c]		No. female spawners/m^2		Estimated area of channel[d] (m^2)
		PINK	PINK + CHUM	PINK	PINK + CHUM	PINK	PINK + CHUM	
1955	36.0	0.158	0.234	252	345	0.094	0.128	2,691.9
1957	32.3	0.365	0.384	647	660	0.268	0.274	2,411.8
1959	49.9	0.959	0.995	1,085	1,126	0.450	0.467	2,411.8
1961	26.6	1.055	1.084	2,308	2,343	0.957	0.971	2,411.8
1963	35.2	1.055	1.115	1,714	1,792	0.711	0.743	2,411.8
1965	52.8	1.268	1.312	1,367	1,389	0.567	0.576	2,411.8
1967	11.2	0.281	0.291	1,460	1,482	0.553	0.561	2,464.2
1969	13.2	0.146	0.165	615	659	0.233	0.249	2,464.2
1971	35.7	0.421	0.423	675	678	0.255	0.257	2,464.2
1973	35.3	0.594	0.781	1,011	1,144	0.441	0.499	2,292.2
1975	64.0	1.151	1.166	1,027	1,041	0.448	0.454	2,292.2
1977	50.5	0.944	1.083	1,005	1,101	0.429	0.470	2,341.0
1979	32.6	0.925	0.940	1,662	1,692	0.710	0.723	2,341.0
1981	79.1	1.575	1.829	1,113	1,205	0.475	0.515	2,341.0

[a] From Table 4.

[b] From Tables 4 and 13.

[c] From Tables 4 and 13.

[d] From Append. 1

Appendix 14. The Fraser River pink salmon catch and escapement data, 1959 - 1981 brood years.

Year	Total escapement[a] (millions)	Total catch[a] (millions)	Total return[a] (millions)	Catch/escapement ratio (-:1)	Escapement as % of total return
1959	1.078	5.381	6.459	4.992	16.7
1961	1.094	0.796	1.890	0.728	57.9
1963	1.953	3.373	5.326	1.727	36.7
1965	1.191	1.080	2.271	0.907	52.4
1967	1.831	11.019	12.850	6.018	14.3
1969	1.529	2.320	3.849	1.517	39.7
1971	1.804	7.903	9.707	4.381	18.6
1973	1.754	4.999	6.753	2.850	26.0
1975	1.367	3.500	4.867	2.560	28.1
1977	2.388	5.785	8.173	2.423	29.2
1979	3.561	10.539	14.100	2.960	25.3
1981	4.488	13.912	18.400	3.100	24.4
Mean	-	-	-	2.847	30.8

[a] From IPSFC Annual Reports.

Appendix 15. Chum spawning distribution in Jones Creek channel, 1973 - 1981.

Year	Enumeration period[a]	Total days counted	% OF TOTAL CHUM COUNTED PER CHANNEL SECTION																
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
1973	Sept. 22 - Oct. 18	289	17.3	14.2	7.6	6.6	6.3	5.5	6.0	6.0	4.2	3.5	3.1	0.7	0	0.7	4.3	6.3	100
1977	Sept. 21 - Oct. 18	988	13.1	3.9	9.0	6.4	7.0	7.6	5.3	5.0	6.9	4.4	5.6	3.5	4.0	1.0	6.5	6.3	100
1979	Sept. 24 - Oct. 23	81	9.9	17.3	3.6	6.9	6.9	1.2	1.2	3.5	6.9	7.4	6.9	3.5	8.6	6.2	6.8	11.1	100
1981	Sept. 18 - Oct. 23	676	6.9	5.3	4.3	4.4	5.2	3.1	1.5	3.1	3.8	1.8	0.7	0.4	0.4	4.6	25.1	30.3	100
Mean (± 95% C.I.)			11.8±3.2	10.2±3.3	7.1±1.6	6.1±0.5	6.4±0.9	4.1±1.5	3.6±2.1	4.7±1.2	5.4±0.7	4.2±1.2	3.6±1.1	1.2±0.6	3.2±2.0	3.4±1.3	10.2±3.6	14.6±5.5	100

[a] Not continuous.

Appendix 16. Fecundity, egg retention and spawning success of chum females in spawning channel and Jones Creek, 1955 - 1981 (n gives sample size).

Year	Fecundity[a]	CHANNEL					CREEK				
		Egg retention[b]		Unspawned females		Spawning success[c]	Egg retention[b]		Unspawned females		Spawning success[c,d]
		(n)	Mean	(n)	No.	(%)	(n)	Mean	(n)	No.	(%)
1955	3,257	———	[e]	———		97.9[f]	———		———		98.8[f]
1956	3,257	———		———		97.9[f]	———		———		98.8[f]
1957	3,257	———		———		97.9[f]	———		———		98.8[f]
1959	3,257		20[f]		0	99.4	———		———		98.8[f]
1961	3,257		20[f]	(28)	2	92.3		0		0	100.0
1963	3,257	———		———		97.9[f]	———		———		98.8[f]
1965	3,257	———		———		97.9[f]	———		———		98.8[f]
1967	3,257		0		0	100.0		0		0	100.0
1969	3,257		0		0	100.0	———		———		98.8[f]
1971	3,257	———		———		97.9[f]	———		———		98.8[f]
1973	3,257	(99)	14	(100)	1	98.6	(51)	15		0	99.5
1975	3,257	———		———		97.9[f]	———		———		98.8[f]
1977	3,257	(45)	48	(47)	2	94.3	(18)	6		0	99.8
1979	3,257	(17)	46		0	98.6	(16)	195		0	94.0
1981[g]	3,257	(31)	14		0	99.6	(31)	14		0	99.6
Mean[h]	-		20	———		97.9		38	———		98.8

[a] No data; used Fraser River chum data averaged for 1966, 1968 (Palmer 1972) and 1978 (R. Harrison), DFO pers. comm.).
[b] Excludes unspawned females.
[c] (Actual egg deposition X 100) - (Potential egg deposition).
[d] Using corresponding channel fecundity.
[e] No data.
[f] Mean of other years.
[g] Chum data for channel and creek combined.
[h] Includes only years with actual data.

Appendix 17. Comparison of egg-to-fry survival rates for chum salmon from Jones Creek and Big Qualicum River spawning channels and from Fraser River.[a]

Brood year	Egg-to-fry survival		
	Jones Creek channel[b]	Big Qualicum River channel No. 2	Fraser River
1955	25.4	-	-
1956	19.1	-	-
1957	47.2	-	-
1958	-	-	-
1959	27.1	-	-
1960	-	-	-
1961	27.2	-	-
1962	-	-	-
1963	40.1	-	-
1964	-	-	13.8
1965	62.6	-	11.6
1966	-	-	12.3
1967	13.8	90.1	23.3
1968	-	80.1	7.1
1969	13.5	76.4	20.1
1970	-	60.6	10.9
1971	17.7	72.9	10.3
1972	-	67.0	11.1
1973	43.9	73.8	17.2
1974	-	76.2	15.0
1975	33.2	68.4	16.5
1976	-	52.3	38.0
1977	47.3	43.9	15.4
1978	-	29.0	11.8
1979	15.4	71.4	24.4
1980	-	-	34.2
1981	85.0	-	-
Mean ± 1S.E.	34.6 ± 5.2	66.3 ± 4.5	17.2 ± 2.1

[a] Data for Big Qualicum River channel from SEP annual summaries; data for Fraser River from M. Farwell (DFO, pers comm.).

[b] See Table 13 for details.

Appendix 18. Coho fry enumeration in Jones Creek spawning channel, 1955 - 1981 broods.

Brood year	No. fry[a]
1955	N.A.[b]
1956	N.A.
1957	42,754+[c]
1959	8,664+
1961	20,700+
1963	19,973+
1965	50,834+
1967	7,612+
1969	2,784+
1971	1,396+
1973	17,794+
1975	2,137+
1977	2,000+
1979	53+
1981	429+

[a] Enumeration period as for pink and chum fry (Table 6).
[b] Not available.
[c] Underestimated; from 200 to 1,000 coho fry still migrated from the channel on last day of count.

Appendix 19 a. Five-day mean surface water temperatures (°C) in Jones Creek (1949, 1952, 1953) and in the channel (1954, 1956).

Date	1949	1952	1953	1954	1956	Date	1949	1952	1953	1954	1956
Jan. 5	-	-	-	-	-	July 5	-	-	-	-	-
10	-	-	0.0[a]	-	-	10	-	-	-	-	-
15	-	-	-	0.6[a]	-	15	-	-	-	-	-
20	-	-	-	-	-	20	-	-	-	-	-
25	-	-	-	-	-	25	-	-	-	-	-
31	-	-	-	-	-	31	-	-	-	-	-
Feb. 5	-	-	-	-	-	Aug. 5	-	-	-	-	-
10	-	-	-	-	-	10	-	-	-	-	-
15	-	-	-	-	-	15	-	-	-	-	-
20	-	-	2.6[a]	-	-	20	-	-	-	-	15.0[a]
25	-	-	-	-	-	25	-	-	-	-	16.1[a]
28	-	-	-	-	-	31	-	-	-	-	15.0
Mar. 5	-	-	-	-	-	Sept. 5	-	-	-	-	15.0
10	-	-	-	-	-	10	-	-	-	-	14.7[b]
15	-	-	-	-	-	15	-	-	-	-	13.2[b]
20	-	-	-	-	-	20	-	13.9[a]	-	-	11.6[b]
25	-	-	-	-	-	25	13.0[c]	15.6[a]	-	13.6	11.0
31	-	-	-	-	-	30	13.2[c]	-	-	11.6	9.6
Apr. 5	-	-	-	-	-	Oct. 5	10.3[c]	12.6[a]	9.0[a]	7.3	9.0
10	-	-	-	-	-	10	7.6[c]	13.9[a]	-	7.5[b]	9.8
15	-	-	-	-	-	15	7.6[c]	9.4[a]	10.0[a]	-	7.9
20	-	-	-	-	-	20	3.9[c]	-	-	8.9	7.8
25	-	-	-	-	-	25	4.3[c]	-	-	6.7	6.8
30	-	-	-	-	-	31	5.2[c]	10.6[a]	8.0[a]	6.2	4.4[a]
May 5	-	-	-	-	-	Nov. 5	-	-	6.0[a]	7.4	-
10	-	-	-	-	-	10	-	7.8[a]	9.5[a]	7.5[b]	-
15	-	-	-	-	-	15	-	-	-	-	-
20	-	-	-	-	-	20	-	-	8.0[a]	-	-
25	-	-	-	-	-	25	-	4.4[a]	-	-	-
31	-	-	-	-	-	30	-	-	-	-	-
June 5	-	-	-	-	-	Dec. 5	-	-	-	-	-
10	-	-	-	-	-	10	-	-	-	-	-
15	-	-	-	-	-	15	-	-	-	-	-
20	-	-	-	-	-	20	-	-	-	-	-
25	-	-	-	-	-	25	-	-	-	-	-
30	-	-	-	-	-	31	-	-	-	-	-

[a] One day's data.
[b] Two-three days' data.
[c] From (Anon. 1949).

Appendix 19 b. Five-day mean surface water temperatures (°C) in Jones Creek spawning channel, 1957 - 1960.

Date	1957	1958	1959	1960
Jan. 5	-	-	-	-
10	-	-	-	-
15	-	-	-	-
20	-	-	-	-
25	-	-	-	-
31	-	-	-	-
Feb. 5	-	-	-	-
10	-	-	-	-
15	-	-	-	-
20	-	-	-	-
25	-	-	-	-
28	-	-	-	-
Mar. 5	-	-	-	-
10	-	-	-	-
15	-	-	-	-
20	-	-	-	-
25	-	-	-	-
31	-	5.9[b]	-	-
Apr. 5	-	6.7	-	-
10	-	6.8	-	6.3
15	-	7.6[b]	-	4.9
20	-	6.9	-	3.8
25	-	6.7	-	5.3
30	-	7.5	-	7.3
May 5	-	9.3[b]	-	7.8
10	-	-	-	8.4
15	-	-	-	8.4
20	-	-	-	8.3
25	-	-	-	-
31	-	-	-	-
June 5	-	-	-	-
10	-	-	-	-
15	-	-	-	-
20	-	-	-	-
25	-	-	-	-
30	-	-	-	-

Date	1957	1958	1959	1960
July 5	-	-	-	-
10	-	-	-	-
15	-	-	-	-
20	-	-	-	-
25	-	-	-	-
31	-	-	-	-
Aug. 5	-	-	-	-
10	-	-	-	-
15	-	-	-	-
20	-	-	-	-
25	-	-	-	-
31	-	-	-	-
Sept. 5	-	-	-	-
10	-	-	-	-
15	13.5	-	-	-
20	11.5	-	11.7[b]	-
25	11.7[b]	-	11.7	-
30	13.0	-	10.8	-
Oct. 5	9.8	-	9.9	-
10	6.8	-	7.9	-
15	9.4	-	9.7	-
20	7.4	-	9.7	-
25	5.2	-	9.4	-
31	-	-	8.6	-
Nov. 5	-	-	-	-
10	-	-	-	-
15	-	-	-	-
20	-	-	-	-
25	-	-	-	-
30	-	-	-	-
Dec. 5	-	-	-	-
10	-	-	-	-
15	-	-	-	-
20	-	-	-	-
25	-	-	-	-
31	-	-	-	-

a,[b] As in Append. 19a.

Appendix 19 c. Five-day mean surface water temperatures (°C) in Jones Creek spawning channel, 1961 - 1965.

Date	1961	1962	1964	1965	Date	1961	1962	1964	1965
Jan. 5	-	-	-	-	July 5	-	-	-	-
10	-	-	-	-	10	-	-	-	-
15	-	-	-	-	15	-	-	-	-
20	-	-	-	-	20	-	-	-	-
25	-	-	-	-	25	-	-	-	-
31	-	-	-	-	31	-	-	-	-
Feb. 5	-	-	-	-	Aug. 5	-	-	-	-
10	-	-	-	-	10	-	-	-	-
15	-	-	-	-	15	-	-	-	-
20	-	-	-	-	20	-	-	-	-
25	-	-	-	-	25	-	-	-	-
28	-	-	-	-	31	-	-	-	-
Mar. 5	-	-	-	-	Sept. 5	-	-	-	-
10	-	-	-	-	10	11.7[a]	-	-	-
15	-	-	-	-	15	10.9	-	-	11.8[b]
20	-	-	-	-	20	12.0	-	-	9.2
25	-	2.9[b]	1.6	-	25	8.9	-	-	11.7
31	-	3.1	3.0	-	30	8.6	-	-	10.1
Apr. 5	-	4.3	3.2	-	Oct. 5	8.6	-	-	11.0
10	-	3.8	4.2	-	10	7.8	-	-	10.1
15	-	5.1	3.1	-	15	9.9	-	-	9.7
20	-	5.6	3.7	-	20	7.8	-	-	8.1
25	-	5.6	3.9	-	25	-	-	-	9.1
30	-	4.2	3.5	-	31	-	-	-	9.4
May 5	-	4.2	4.6	-	Nov. 5	-	-	-	-
10	-	5.9	5.1	-	10	-	-	-	-
15	-	6.0	4.7	-	15	-	-	-	-
20	-	7.4	5.5	-	20	-	-	-	-
25	-	7.8	4.3	-	25	-	-	-	-
31	-	8.4	6.0[b]	-	30	-	-	-	-
June 5	-	8.0	-	-	Dec. 5	-	-	-	-
10	-	-	-	-	10	-	-	-	-
15	-	-	-	-	15	-	-	-	-
20	-	-	-	-	20	-	-	-	-
25	-	-	-	-	25	-	-	-	-
30	-	-	-	-	31	-	-	-	-

a,[b] As in Append. 19a.

Appendix 19 d. Five-day mean surface water temperatures (°C) in Jones Creek spawning channel, 1966 - 1969.

Date	1966	1967	1968	1969	Date	1966	1967	1968	1969
Jan. 5	-	-	1.4	-	July 5	-	-	-	-
10	-	-	1.7	-	10	-	-	-	-
15	-	-	1.8	-	15	-	-	-	-
20	-	-	2.4	-	20	-	-	-	-
25	-	-	4.0	-	25	-	-	-	-
31	-	-	-0.6	-	31	-	-	-	-
Feb. 5	-	-	2.6	-	Aug. 5	-	-	-	-
10	-	-	2.2	-	10	-	-	-	-
15	-	-	1.8	-	15	-	-	-	-
20	-	-	2.4	-	20	-	-	-	-
25	-	-	4.4	-	25	-	-	-	-
28	-	-	4.4	-	31	-	-	-	-
Mar. 5	-	-	5.1	-	Sept. 5	-	-	-	-
10	-	-	4.2	-	10	-	-	-	-
15	-	-	4.4	-	15	-	12.2[b]	-	-
20	-	-	5.1	-	20	-	14.3	-	11.9
25	-	-	5.1	-	25	-	12.9	-	12.2
31	4.1	-	4.7	-	30	-	13.5	-	11.4
Apr. 5	4.1	-	4.3	-	Oct. 5	-	11.9	-	9.8
10	4.1	-	4.5	-	10	-	11.2	-	9.7
15	3.5	-	3.4	-	15	-	10.3	-	8.0
20	3.8	-	3.2	-	20	-	8.8	-	7.2
25	4.4	-	4.1	-	25	-	7.0	-	9.5
30	4.6	-	5.3	-	31	-	7.1	-	9.3
May 5	5.8	-	4.7	-	Nov. 5	-	8.4	-	8.4
10	6.6	-	5.3	-	10	-	8.0	-	7.3
15	5.8	-	6.8	-	15	-	7.3	-	6.5
20	5.8	-	7.7	-	20	-	7.6	-	5.6
25	4.8[b]	-	7.2	-	25	-	7.1	-	4.7
31	-	-	7.9[b]	-	30	-	5.3	-	4.0
June 5	-	-	-	-	Dec. 5	-	4.2	-	3.2
10	-	-	-	-	10	-	3.3	-	2.7
15	-	-	-	-	15	-	1.7	-	4.7
20	-	-	-	-	20	-	1.7	-	3.4
25	-	-	-	-	25	-	1.7	-	4.2
30	-	-	-	-	31	-	4.1	-	2.9

a,[b] As in Append. 19a.

Appendix 19 e. Five-day mean surface water temperatures (°C) in Jones Creek spawning channel, 1970 - 1973.

Date	1970	1971	1972	1973	Date	1970	1971	1972	1973
Jan. 5	2.1	-	-	-	July 5	-	-	-	-
10	1.7	-	-	-	10	-	-	-	-
15	0.7	-	-	-	15	-	-	-	-
20	0.0	-	-	-	20	-	-	-	-
25	2.9	-	-	-	25	-	-	-	-
31	2.8	-	-	-	31	-	-	-	-
Feb. 5	2.8	-	-	-	Aug. 5	-	-	-	-
10	3.8	-	-	-	10	-	-	-	-
15	4.0	-	-	-	15	-	-	-	-
20	4.2	-	-	-	20	-	-	-	-
25	3.6	-	-	-	25	-	-	-	-
28	3.3	-	-	-	31	-	-	-	-
Mar. 5	1.6	-	-	-	Sept. 5	-	-	-	-
10	3.0	-	-	-	10	-	13.1[b]	-	-
15	4.2	-	-	-	15	-	11.9	-	-
20	3.9	-	-	-	20	-	10.7	-	13.3[a]
25	4.4	-	-	-	25	-	11.7	-	12.7
31	4.6	-	5.0[a]	-	30	-	10.1	-	12.2
Apr. 5	5.2	-	4.3	-	Oct. 5	-	10.5	-	10.5
10	4.1	-	3.1	-	10	-	10.4	-	9.5
15	4.9	-	3.7	-	15	-	9.3	-	8.6
20	6.4	-	4.8	-	20	-	6.0	-	9.7
25	5.7	-	4.5	-	25	-	6.5	-	9.2
30	5.9	-	4.1	-	31	-	3.0	-	7.9
May 5	7.9	-	6.9	-	Nov. 5	-	4.7[b]	-	4.7
10	7.4	-	5.2	-	10	-	-	-	2.0
15	7.3[b]	-	6.2	-	15	-	-	-	3.7
20	-	-	6.1	-	20	-	-	-	2.0
25	-	-	5.8[b]	-	25	-	-	-	1.7
31	-	-	-	-	30	-	-	-	2.9
June 5	-	-	-	-	Dec. 5	-	-	-	3.7
10	-	-	-	-	10	-	-	-	3.4
15	-	-	-	-	15	-	-	-	3.9
20	-	-	-	-	20	-	-	-	3.6
25	-	-	-	-	25	-	-	-	3.7
30	-	-	-	-	31	-	-	-	1.9

a,[b] As in Append. 19a.

Appendix 19 f. Five-day mean surface water temperatures (°C) in Jones Creek spawning channel, 1974 - 1977.

Date	1974	1975	1976	1977	Date	1974	1975	1976	1977
Jan. 5	0.0	-	-	-	July 5	-	-	-	-
10	0.0	-	-	-	10	-	-	-	-
15	0.9	-	-	-	15	-	-	-	-
20	3.2	-	-	-	20	-	-	-	-
25	3.3	-	-	-	25	-	-	-	-
31	2.4	-	-	-	31	-	-	-	-
Feb. 5	2.4	-	-	-	Aug. 5	-	-	-	-
10	2.6	-	-	-	10	-	-	-	-
15	2.9	-	-	-	15	-	-	-	-
20	3.2	-	-	-	20	-	-	-	-
25	3.0	-	-	-	25	-	-	-	-
28	3.1	-	-	-	31	-	-	-	-
Mar. 5	2.6	-	-	-	Sept. 5	-	-	-	-
10	1.6	-	-	-	10	-	-	-	-
15	2.9	-	-	-	15	-	-	-	-
20	3.4	-	-	-	20	-	14.4[a]	-	12.2[b]
25	3.3[b]	-	-	-	25	-	13.6	-	11.1
31	-	-	2.2[b]	-	30	-	13.2	-	11.0
Apr. 5	-	-	3.5[b]	-	Oct. 5	-	14.8	-	10.0
10	-	-	6.0	-	10	-	10.7	-	8.8
15	-	-	5.7	-	15	-	11.5	-	8.3
20	-	-	5.6	-	20	-	9.7	-	7.6[b]
25	-	-	5.7	-	25	-	7.8	-	-
30	-	-	6.6	-	31	-	-	-	-
May 5	-	-	6.9	-	Nov. 5	-	-	-	-
10	-	-	7.8	-	10	-	-	-	-
15	-	-	7.5	-	15	-	-	-	-
20	-	-	7.7	-	20	-	-	-	-
25	-	-	7.9	-	25	-	-	-	-
31	-	-	7.8[a]	-	30	-	-	-	-
June 5	-	-	-	-	Dec. 5	-	-	-	-
10	-	-	-	-	10	-	-	-	-
15	-	-	-	-	15	-	-	-	-
20	-	-	-	-	20	-	-	-	-
25	-	-	-	-	25	-	-	-	-
30	-	-	-	-	31	-	-	-	-

a,b As in Append. 19a.

Appendix 19 g. Five-day mean surface water temperatures (°C) in Jones Creek spawning channel, 1978 - 1982.

Date	1978	1979	1980	1981	1982	Date	1978	1979	1980	1981	1982
Jan. 5	-	-	-	-	-	July 5	-	-	-	-	14.4[a]
10	-	-	-	-	0.5[a]	10	-	-	-	-	15.7[a]
15	-	-	-	-	-	15	-	-	-	-	-
20	-	-	-	-	-	20	-	-	-	-	-
25	-	-	-	-	-	25	-	-	-	-	-
31	-	-	-	-	3.0[a]	31	-	-	-	-	-
Feb. 5	-	-	-	-	3.0[a]	Aug. 5	-	-	-	-	-
10	-	-	-	-	0.0[a]	10	-	-	-	-	-
15	-	-	-	-	-	15	-	-	-	-	-
20	-	-	-	-	3.5[b]	20	-	-	-	-	13.0
25	-	-	-	-	2.4[a]	25	-	-	-	-	14.8
28	-	-	-	-	-	31	-	-	-	-	13.9
Mar. 5	-	-	-	-	-	Sept. 5	-	-	-	-	14.1
10	-	-	-	-	4.4[b]	10	-	-	-	-	13.2
15	-	-	-	-	-	15	-	-	-	-	9.9
20	-	-	-	-	3.7[a]	20	-	14.7[b]	-	14.8[b]	12.8
25	-	-	-	-	4.5[b]	25	-	14.3	-	13.6[b]	13.1
31	-	-	-	-	3.7[b]	30	-	13.0	-	14.7	10.6
Apr. 5	-	-	-	-	4.6[b]	Oct. 5	-	12.7	-	12.3[b]	8.9
10	5.4[b]	-	-	-	4.2[b]	10	-	12.2	-	11.6	-
15	5.0[b]	-	-	-	3.8[b]	15	-	12.0	-	10.2	-
20	5.9	-	-	-	3.0[b]	20	-	9.9	-	11.7[b]	-
25	6.5	-	6.5[b]	-	4.2[b]	25	-	-	-	9.9	-
30	6.7	-	6.3[a]	-	4.4[b]	31	-	-	-	12.5[a]	-
May 5	6.0[b]	-	-	-	4.4	Nov. 5	-	-	-	-	-
10	6.2[b]	-	-	-	5.0	10	-	-	-	-	-
15	-	-	-	-	5.3	15	-	-	-	-	-
20	-	-	9.4[b]	-	5.3	20	-	-	-	-	-
25	-	-	-	-	6.0[b]	25	-	-	-	-	-
31	-	-	8.5[a]	-	6.6[b]	30	-	-	-	-	-
June 5	-	-	-	-	7.0[a]	Dec. 5	-	-	-	-	-
10	-	-	-	-	9.0[b]	10	-	-	-	-	-
15	-	-	-	-	-	15	-	-	-	-	-
20	-	-	-	-	-	20	-	-	-	-	-
25	-	-	-	-	-	25	-	-	-	-	-
30	-	-	-	-	11.6[a]	31	-	2.5[a]	-	1.0[a]	-

a,[b] As in Append. 19a.